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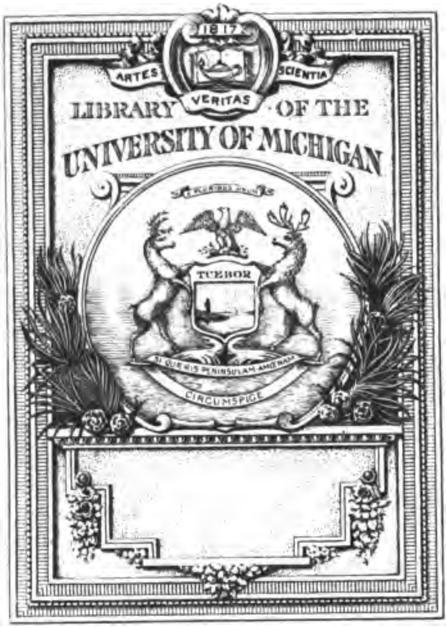
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PHILOSOPHICAL CONVERSATIONS:

OR, A NEW

SYSTEM

OF

PHYSICS,

By Way of DIALOGUE.

With Eighty Nine COPPER PLATES.

Written in French by Father *REGNAULT*
of the SOCIETY of JESUS.

Tranſlated into Engliſh and illuſtrated with NOTES

BY

THOMAS DALE, M. D.

VOL. III.

LONDON,
Printed for W. INNYS in St. *Paul*'s Church-yard,
C. DAVIS the Corner of *Pater-Noſter-Row*, and
N. PREVOST againſt *Southampton-ſtreet* in the *Strand*.
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PHILOSOPHICAL CONVERSATIONS
BETWEEN
Ariſtus and *Eudoxus.*

CONVERSATION I.

Upon the Origin, Growth, Perpendicularity and Nutritive Juices of Plants.

Eudox. DOES Botany, or the Knowledge of Plants, charm you, *Ariſtus*, as well as me? Innocence and Pleaſure attend it.

Ariſt. I always lov'd to acknowledge in a wonderful multitude and variety of Plants the fertile Hand which has ſpread them over the whole Surface of the Earth, not ſo much to adorn and embelliſh it, as to preſerve to us Life and Health. What ſtrikes my Curioſity at preſent, is the Nature itſelf, and internal Structure of Plants, their Origin, nutritive Juices, Vegetation, Direction, Generation, Fruitfulneſs, Culture, ſingular Properties, and finally, their Maladies. I ſhall be charmed to know your Sentiment on this head.

Eud. A Plant is an organized Body, which is merely vegetative; that is to ſay, which nouriſhes itſelf inwardly, which grows and propagates Bodies of the ſame Species, but without a Soul capable of moving or feeling. Thus one obſerves in Plants, Organs fit for receiving, preparing, refining and diſtributing the nutritive Juices, but none which ſeem ordained for Motion or Senſation.

According to the Obſervations of that famous Botaniſt, *Malpighi* *, the principal Organs of Plants are the ligneous Fibres (*m*), the Tracheæ (*k*), and the Utriculi (*n*), Fig. 1.

The Fibres are ſtrait Pipes, oblong, diſpoſed according to the Length of the Plant, and commonly interwoven in form of Threads [a]. The Tracheæ are groſſer Pipes, formed of a Lamina of a ſpiral Figure, diſpoſed from below upward, according to the length of the Plant, ſometimes united in their Courſe, ſometimes enlarged after the Manner of Cellules, like unto the Tracheæ and Lungs of Inſects;

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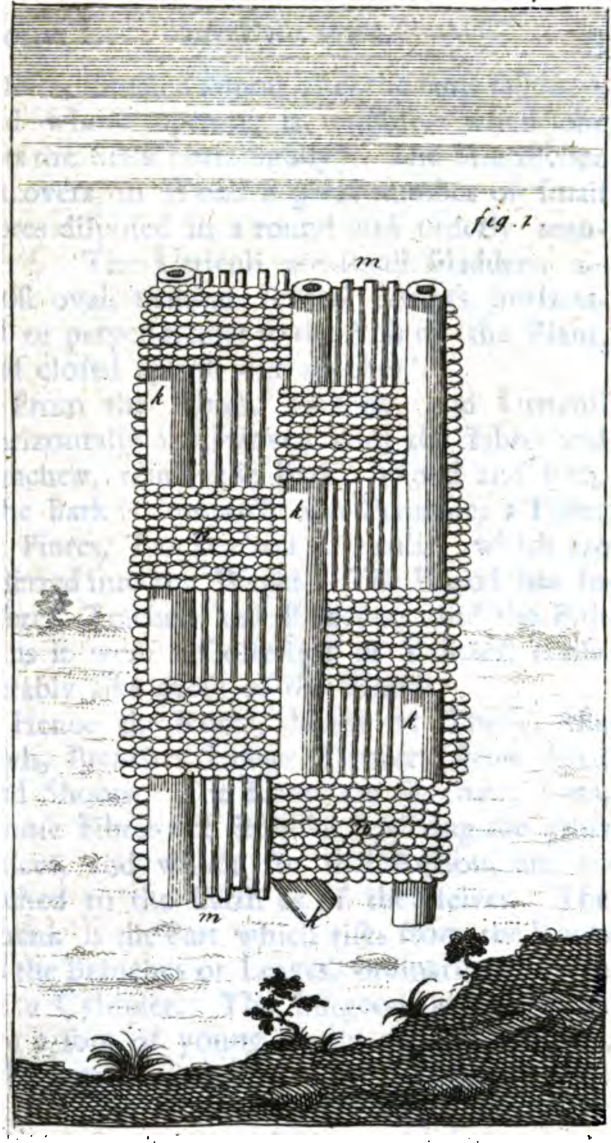
* Anatomes Plantarum Idea. p. 3. Anat. p. 8.

[a] Anat. p. 3.

Vol. III. p. 2.



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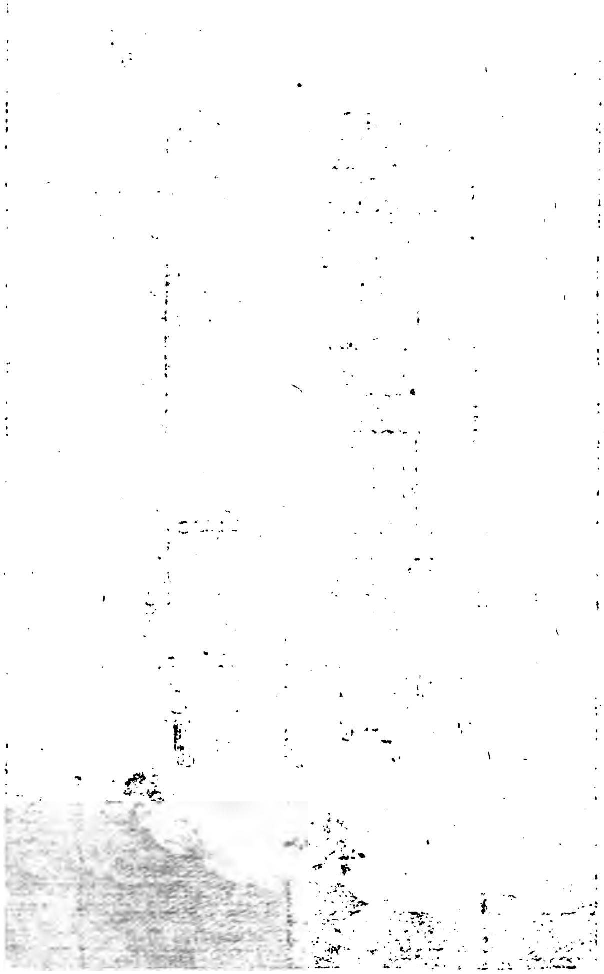

Inſects; ſituated almoſt after the ſame faſhion[b], and whoſe opening is ſenſible, when one cuts the Stalk horizontally[c]. The Microſcope diſcovers in Wood a great number of ſmall Pores diſpoſed in a round and orderly manner[d]. The Utriculi are ſmall Bladders, almoſt oval, making ſeveral Ranges horizontal or perpendicular to the Axis of the Plant, and cloſed againſt one another[e].

From the Fibres, Tracheæ, and Utriculi horizontally interwoven with the Fibres and Tracheæ, reſult the Bark, Wood and Pith. The Bark is compos'd of a Pellicule, a Tiſſue of Fibres, Tracheæ and Utriculi[f], which are inſerted into the Wood. The Wood has its Fibres, Tracheæ and Bladders; and the Pith is as it were a Collection of Veſicles, conſiderably like thoſe of the Wood.

Hence the Roots, Shank or Trunk, the Buds, Branches, Leaves, Flowers, Fruit, Seed and Shoots. The Roots are the hairy Parts, whoſe Fibres are fitter for receiving the groſs Juices, and which, for that Reaſon, are attached to the Earth as of themſelves. The Shank is the Part which riſes from the Roots to the Branches or Leaves, ordinarily in form of a Cylinder. The Burgeons and Branches are a ſort of young Sprigs, or ſmall Plants, which grow out of the Shank. The Leaves

[b] Anat. p. 14.

[c] Anat. Pl. Idea, p. 3.

[d] Mem. de Leipſick, 1723. Janv. p. 36.

[e] Anat. Plant. Idea. p. 2.

[f] Ibid. p. 1.

are Productions of the Fibres of the Branches or of the Shank. Theſe Fibres being accompanied with Tracheæ and Utriculi, iſſue out of a Stalk, are extended at firſt in largeneſs, and then after ſome windings are contracted, and form the Plane or Circumference of the Leaf. The Flower is almoſt like the Leaf, a Contexture of Fibres, which proceed from the Bark and Wood, but finer; and according to the Texture and Arrangement of the Leaves, it is an Anemony, a Roſe, a Pink. The Fruit, which one ſees to grow ordinarily in the middle of the Flower, contains the Seed or Grain; and what is the Grain? It is a ſmall Plant ready to be opened.

Ariſt. Then you believe, *Eudoxus*, that every Plant proceeds from a Seed, and that the Seed is a ſmall Plant fully formed, which is only unfolded in growing.

Eud. Either every Plant proceeds from a Seed which is a ſmall Plant already formed, and delineated in Miniature by Nature; or elſe there are Plants, which reſult from the fortuitous Concourſe of certain Juices diverſly agitated. Now it is inconceivable that there are Plants, which proceed from ſuch a Concourſe. For, 1. We only ſee Plants perfectly alike to proceed from the ſame Species. Could then a fortuitous Concourſe be ſo regular as to cauſe ſo much Uniformity in an Infinity of Plants? 2. If it is a fortuitous Concourſe which makes Plants, why do we not daily ſee new ones ſpring up? We remark none or obſerve very few Species, which have been unknown till this preſent time. Is chance confined within ſo narrow Bounds? 13. The Mechaniſm or Structure of Plants is ſo compounded, and that ſo delicately, that all the Skill of the moſt enlightened and penetrating Men united in the ſame Deſign, cannot mix Juices artfully enough, ſo as to form the moſt imperfect Plant; could Chance alone then form one? Finally, whenever we perceive the ſmalleſt Part of a growing Plant, we ſee it wholly formed. Would Nature then affect not to ſhew us the Plant, but when Chance had perfected it? Every Plant therefore proceeds from a Seed; and that Seed is a ſmall Plant, which needs only to be explicated. The Eggs of Animals and Seeds of Plants are almoſt the ſame thing. The Animal and Plant contained in Miniature, the one in its Egg, and the other in its Seed are unfolded; and this is their original and growth.

Ariſt. Though we have ſome time ſince diſcovered the Secrets which Plants made uſe of to conceal their Seed from our Eyes, there are ſome which ſtill remain unknown to us.

Eudox. It is true: But, 1. The Number of Plants which certainly bear Seed is incomparably the greateſt; and there is much more in it than Prejudice. 2. How many Plants only bear very ſmall Seed, and ſuch as may eſcape the moſt curious Eye?

Ariſt. But after all, *Eudoxus*, if a Plant can with the Sap form a ſmall Plant, what need is there to imagine in every Plant a Seed which is a little Plant?

Eudox. The Plant may well afford Paſſage to the Sap, in order to convey and diſtribute Nouriſhment. The Sap may nouriſh the Plant. But the Plant being only a Bundle of Fibres, Bladders, and Veſſels deſtitute of action, and the Sap being only a fortuitous Collection of Salts, Particles of Water, and Juices received into the Plant, the Plant and Sap cannot form Roots, Trunk, Branches, Leaves, and an organized Body, which ſurpaſſes the Underſtanding of Men. The Plant when it propagates, only expoſes to Light what the hand of the Creator has entruſted it with from the beginning of the World. And if what they report is true, that they have ſeen in *Sileſia*, and at the Court of *Vienna*, one Shank alone bear fifteen great Ears of Barley, which riſing after the manner of Pipes in an Organ, formed a very fine Plume; the Reaſon is, becauſe probably fourteen Seeds being contained in a larger one, were unfolded with it.

Ariſt. Therefore the firſt Plant of every Species muſt have contained in its Boſom all thoſe which have or ſhall grow out of it; and conſequently the Author of Nature muſt at firſt have put into the leaſt Seed an infinite number of Seeds.

Eudox. It is ſufficient that he has put into it all thoſe which have or ſhall grow out of it to the end of the World. Now is it neceſſary that this Number be infinite?

Ariſt. In vain you encloſe in the ſmalleſt Seed an almoſt infinite Number of Plants already formed, if the Muſhroom grows without Seed; but it grows without Seed. For in a word, we ſee it grow ſuddenly out of a Dunghill, and to ſpeak more preciſely from Horſe-dung *. Spread Horſe-dung upon the Earth, make a ſort of Bed of it, water it, and after a certain time the Bed is a Neſt of Muſhrooms.

Eudox. If there are inviſible Seeds ſcatter'd in divers parts, as there are inviſible Eggs of Inſects, and if theſe Seeds have need of certain Juices in order to their unfolding, it only follows from the Method of making Muſhrooms grow at *Paris*, that there are ſome Seeds of Muſhrooms diffuſed in divers parts, and that Horſe-dung is a Species of Earth or Matter fit for cauſing them to ſpring up. Now it is probable that there are inviſible Seeds diffuſed in divers parts, which only wait for certain Juices and Circumſtances, in order to be opened. For in a word, whence proceed the black Poppies which grow out of the burnt Heaths in *Languedoc*, *Provence*, and the Iſlands of the *Archipelago?* Whence came that Species of Plant which covered ſeveral

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* Hiſt. de l'Acad. 1707. p. 47.

Acres of Earth laid waſte by the Fire of *London?* Becauſe probably new Juices and new Circumſtances make the Seeds open, which were already ſcatter'd into divers parts. A thouſand Chances may tranſport the ſmall Seeds, and their ſmallneſs itſelf protects them from Injuries from without, preſerves and renders them more delicate than the choiceſt Juices.

Ariſt. I muſt own, *Eudoxus*, your Syſtem is at leaſt probable; and it ought naturally to explain the growth and vegetation of Plants.

Eudox. Let us in the firſt place examine the Juices, and after that we ſhall ſee the Plants grow as of themſelves. The nutritive Juices of Plants are Earths, Oils, Salts, and eſpecially Water. Different ſorts of Plants afford thoſe Principles in Diſtillation *; and it is well known how Water contributes to the accretion of Plants. In Winter they ſet over the Chimney a ſort of Glaſs-bottles full of Water. Upon the Surface of the Water they put the Roots of Tulip, Anemony, Jonquil, *&c.* The heat of the Fire is communicated to the Water. The agitated Particles of Water penetrate the Roots, and explicate them. You ſee the Roots deſcend into the Water, the Shank aſcend, and Flowers grow in the height of Winter.

Would you have a Sallet formed in a little time? Of porous Earth, which they give us

* Mariote des Plantes, p. 23, 33, *&c.*

for Earth of *Egypt*, they make a Veſſel with a long Neck, which they fill up with Water. Upon the external Surface of the Veſſel they apply ſome wet Seeds of Radiſhes, Creſſes, or other Herbs. The Pitcher tranſpires. The Water, which is filtred thro' its Pores, unfolds the Seed, and conveys to it Nouriſhment and Life; and you are ſurprized to ſee the external Surface of the Veſſel, tho' very hard, produce Herbs which would grow more ſlowly in the beſt cultivated Earth. Divers Salts being diffuſed in the Air, and after that mixt with Rains or Vapours, penetrate the Earth as far as the Roots, and dilate the terreſtrial Particles. Theſe Particles, with the Salts and Water, are the ordinary Juices of Plants.

Ariſt. Nevertheleſs according to the famous Experiment of *Van-helmont*, Water alone ſeems to nouriſh Plants. He took two hundred pounds of Earth dried in the Oven, and having water'd it with Rain-water, he planted in it a Willow which weighed five pounds. He ſhut up this Earth on all ſides, in a Veſſel which had ſmall holes above, for giving air to the Earth, and watering it with Rain-water from time to time. At the end of five Years the Willow weighed one hundred and ſixty-five pounds; and the Earth, after it was dried again in the Oven, weighed ſtill two hundred pounds wanting two ounces *. Is it not evident that the Water alone had nouriſhed the Plants?

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* Duhamel. *De corporum affectionibus*, p. 52. Journ. des Sçav. 1671. 30 Mar. p. 14.

Eudox. No; for in a word, 1. It is ſufficiently evident that the Earth, after having been put into the Oven, was as dry the ſecond time as the firſt? 2. Rain-water carries along with it terreſtrial Parts, ſince it depoſites ſuch in the bottom of Reſervoirs. 3. Duſt and different Salts which the Air carries about might paſs with the Air into the Veſſel thro' the ſmall holes: therefore this Experiment does not demonſtrate that Water alone nouriſhes Plants. Would Dung render Land ſo fertile, if it did not furniſh it with Juices?

The ſame Juices nouriſh different Plants, and produce different Fruits, according to the different Configurations which they find and receive in the Veſſels of Plants. Should you graft the Bon-Chretien Pear upon a wild one, the ſame Juice which in this laſt would have produced but very ſmall Pears, and thoſe of a bad Taſte, will produce very large ones, and of an excellent Flavour, after it has paſt into the Branches which the Graff ſhoots out. Graft upon one of thoſe Branches a Branch of a wild Pear-tree: it only bears very ſmall Pears, and of a bad Taſte *.

Ariſt. This Experiment may be confirmed by another. Let eight or ten pounds of Earth be put into a Veſſel: three or four thouſand different Plants might find their Nouriſhment in this Earth, and in the Rains which water it.

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* Mariote des Plantes, p. 36.

Now this quantity of Earth and Rain being united together, would not be ſufficient to furniſh ſuch a Quantity of different Nouriſhment to ſo great a number of Plants. In order to this, it would be neceſſary that the whole Maſs of this Earth and Water weighed at leaſt four or five hundred pounds, and yet it would ſcarcely weigh twenty; therefore different ſorts of Plants may be nouriſhed with the ſame Juices.

Eudox. Theſe Principles being granted, one may eaſily comprehend the Growth and Vegetation of Plants. The ſmall Plant has in its Seed, at leaſt ordinarily, even before it ſprings up, its little Root, Stalk, Leaves and Pulp or Fleſh which encompaſſes it, ſeparated into two Lobes united by a Species of Thread to the Extremity of the little Root and Stalk. The nutritive Juices being puſh'd by the efficacy of Gravity, by their Motion proper to Liquidity, by the Action of the Spring of the Air which ſurrounds them, or by a certain Fermentation, inſinuate themſelves into the Seed, penetrate the Pulp or Fleſh of the little Plant, ſhoot out thence into the Fibres of the Roots, and from the Stalk into the Leaves, folded up into a ſmall Maſs inſenſible or almoſt ſo, ſwell the Roots and Leaves, and make them ſtrait, as the Air which is made to enter into a flexible and winding Tube, makes it ſtrait; the Action which ſtraitens the Leaves and Roots, unfolds them by giving them oppoſite Directions.

This Explication produces a regular Figure of a Plant; and this is properly the Growth of the Plant.

The Growth of Plants is ſenſible in the French-Bean. It is a Bean compoſed of two Lobes, which are as it were the Body of the Bean, and of a ſmall Plant contained within the two Lobes: The Lobes contain the Pulp or Fleſh. One may diſcern in the Plant a ſmall Stalk faſtened to the two Lobes by two Species of Bands which are two ſmall Channels. One Extremity of the Stalk is terminated in a Point, and that is the little Root; the other in ſmall Leaves folded over one another. During the Summer, ſoak in Water the end of the Bean fartheſt diſtant from the Bud: the Water which is filtred through the Subſtance of the impregnated Lobes, carries off with it ſome Particles of the Seed or Matter of the Lobes, paſſes through the two ſmall Ducts into the Stalk, and runs into the Pipes of the Roots and Leaves. In a few days you may ſee the Roots unfolded, lengthned and enlarged. Afterwards the ſmall Point is extended into Roots, and deſcends towards the Water. Whenever it has reached the Water, it ſucks it, and tranſmits it to the Stalk and Leaves, which are explicated, lengthened and enlarged more and more. Thus the French-Beans grow. The ſame may be obſerved in the Seed of Gourds, Cucumbers, and Melons *. And ſuch probably,

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* Mariote des Plantes, p. 46, 47.

bly, or at leaſt well nigh, is the growth of other Plants.

When the Burgeon is in the Earth, the Pulp or Seed impregnated with Water is at firſt a Source of very delicate Nouriſhment to it, until it hath ſhot out Roots capable of drawing and digeſting groſſer Juice. The Root is as it were the Stomach of the Plant.

Ariſt. But why does the Root ſink into the Earth, while the Stalk riſes out of it, and riſes perpendicularly to the Horizon? This is a ſort of Affectation. For the Root is often found upward at firſt, and the Stalk downward. The Root bows itſelf in order to deſcend, as one may obſerve in the Phaſeolus, and the Stalk makes an Angle in order to aſcend.

M. *Dodard* planted in a Pink-pot ſix Acorns, with the Point of their Burgeon upward, as perpendicular as poſſible: And two Months after, having taken off the Earth from them, he found that all the Roots had made an Angle to reach downward, as if they had been ſenſible of the Botaniſt's fraud *. What is it that gives to the Root and Stalk this kind of oppoſite Biaſs? This Direction ſtrikes few Perſons, becauſe it is common; and yet it ſeems wonderful when one conſiders it nearly, and like a Philoſopher.

Eud. It is probable that the Pores and Pipes of the Root are greater than thoſe of the

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* Hiſt. de l'Acad. 1702. p. 48.

Stalk; ſince the Root has always paſt for the Stomach of the Plant, in which the groſs Juices are digeſted. Wherefore when the nutritive Juices run from the Pulp into the little Plant thro' the fibrous Ducts which unite it to the Pulp, the groſſer ought to paſs into the Root, and the more volatile into the Stalk.

This being granted, let the little Plant be turned upſide down, or not, 1. The Root ought to deſcend, and ſink into the Earth. For the weightieſt part ought to deſcend and ſink. Its exceſs of Gravity gives it a Direction downward. Now the heavieſt Part is the Root, ſince it attracts the groſſeſt and heavieſt Juice. 2. On the contrary, the Stalk ought to aſcend. It muſt take the Direction which the volatile Juices give it; ſince it only attracts the refined Juices. But theſe Juices being thruſt upward, as Vapours by the Air, by the Matter which ſurrounds them, or by virtue of the Fermentation, give the Stalk which receives them a Direction upward. When the Root has reach'd the Earth, and is attach'd to it, the Juices digeſted and ſubtilized in the Root, which they have run thro' from below upward, and being protruded into the Stalk, as into ſo many capillary Pipes, with a vertical Direction, direct it perpendicularly to the Horizon; after the ſame manner almoſt as the magnetic Matter, which runs thro' the Needle touched with the Loadſtone from below upward, gives to it its own Direction. The Plant takes ſuch a Direction with ſo much the more eaſe, becauſe the Air ſurrounds it on all ſides, and the Preſſure parallel to the Horizon is equal on all ſides, and ſtronger than the perpendicular; whence the Flame has always a vertical Direction, even while the Candle is placed obliquely to the Horizon.

You will aſk, perhaps, why the Stalk is more perpendicular to the Horizon than the Root, which often trails only without piercing.

Ariſt. That is becauſe the Stalk, as ſoon as it has got into the Air, meets with no Reſiſtance to its Motion upward; on the contrary, the Root, in proportion as it deſcends, always encounters a great Reſiſtance to its Motion downward into the Earth *. But thro' what does the nutritive Juice aſcend from the Roots? Is it thro' the Bark, Wood or Pith?

Eud. Probably it aſcends both thro' the Bark, Wood and Pith. Thro' the Bark; for hollow Trees in whoſe Trunks there remains no more Wood than is neceſſary to ſupport the Bark, do not for all that ceaſe to live and to produce. But cut off from the Bark one intire and whole Circle, the Plant is killed by it ſooner or later. 2. Thro' the Wood; the Wood has its perpendicular Fibres; why then ſhould they not draw Juice from the Roots? Thus green Wood is wholly impregnated with Juices. 3. Thro' the Pith; the Pith is a ſort of Spunge, fit for ſucking up liquid Aliment *. One ſingle Fact ſufficiently proves that the Juices aſcend thro' the Bark, Wood and Pith. In *Languedoc*, when they graff the Olive-trees in the Month of *May*, they cut the Bark horizontally three or four Fingers in Breadth, round about the Trunk or Branches; ſo that they uncover the Wood, or ligneous Body a little above the Graff. The Branches above the Graff at length die; no doubt becauſe they are deprived of the nutritive Juice which ought to aſcend thro' the Bark. But they do not die 'till after they have born the ſame year Leaves as uſual, Flowers and Fruit, the double of what they uſed to bear †. Thro' what has the Nouriſhment of ſo many Leaves, Flowers and Fruit aſcended, if not thro' the Fibres of the Wood, and Veſicles of the Pith? The Pith of the Plants, as well as the Marrow of Animals, is a Collection of ſmall Veſicles which ſeem deſtin'd to filter and elaborate finely a Juice for the Nouriſhment of

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* Hiſt, de l'Acad. 1702. p. 48.

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* As the Pith in Quills grows dry and uſeleſs after the Quill is full grown, we may obſerve the ſame in the Pith of Trees, which is always ſucculent and full of Moiſture, while the Shoot is growing, by the Expanſion of which the tender ductile Shoot is diſtended in every part, its Fibres being at the ſame time kept ſupple by this Moiſture; but when each Year's Shoot is full grown, then the Pith gradually drys up, and continues for the future dry and kickſey, its Veſicles being ever after empty; Nature always carefully providing for the ſucceeding Year's Growth, by preſerving a tender ductile part in the Bud replete with ſucculent Pith. *Hale's vegetable Staticks.*

† Hiſt. de l'Acad. 1709. p. 51.

Flowers and Fruits. Hence according to the Obſervations of M. *Magnol*, Plants which have plenty of Pith, as the Roſe-buſh and Lilach, have alſo very many Flowers and Seeds.

Ariſt. This Fact brings to my mind an Elm in the *Tuilleries*, which in the beginning of Spring, tho' it was wholly ſtript of its Bark from the Root to the Branches, nevertheleſs ſhot out Sap into all its Parts, and preſerved its Leaves during the whole Summer, but with leſs vigour than the others[g].

Eudox. The Force which makes the Sap aſcend, makes the Branches ſpring out of the Trunk. The Branches are properly ſmall Plants, which only ſpring out of the principal Plant, and whoſe Roots remain attach'd to the Trunk. The principal Plant is a Compoſition of almoſt an infinite Number of ſmall ſimilar Plants. Hence if one encloſe the Stalk with Earth, it ſhoots out Roots from all Parts[h]. And a Tree that has been lopped, in a ſhort time appears adorned with ſmall Branches. A Branch of a Fig-tree ſet in the Earth ſhoots forth Roots, and in a ſhort time becomes an intire Plant.

Ariſt. But how does one Part become the intire Whole?

Eud. Since we cannot conceive that an organized Part is formed a-new, the Branch contains in itſelf ſmall Roots, which could not be unfolded unleſs it were ſeparated from the Tree, and put into the Earth. The Contact of the Earth, and the Nouriſhment which they immediately receive from it, determine them to ſpread and appear. And one ſees a Whole iſſue out of a Part.

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[g] Hiſt. de l'Acad. 1708. p. 50.

[h] Mem. de l'Acad. 1701. p. 239.

Ariſt. At leaſt the Branches, not being perpendicular to the Horizon, ought to be carried downward by their Weight.

Eudox. Their Weight gives them a perpendicular Direction downward. The nutritive Juices, which impel them, or which they receive, have and give to them a ſtronger Direction upward; and yielding chiefly to the ſtrongeſt, they ordinarily take an oblique Direction, which approaches more to the perpendicular upward, than to the perpendicular downward.

The Branches at laſt with their Juices terminate in Leaves. But if the Leaves draw Juice from the Roots by the Branches and the Stalk, they likewiſe receive ſome immediately from Rain, Dew or Vapours, with which the Air is always charged; and this laſt Juice deſcends as far as the Roots. In ſhort, 1. The Leaves, as well as Stalks, have generally ſmall Points or Threads, which appear like ſo many ſmall Tubes for ſucking up the Vapours and Dew. 2. Cut off a ſmall Branch of a Tree, or of ſome Herb, as Parſley; ſoak only the End of its Leaves in Water; the little Branch is preſerved green three or four days, even in Summer; if it is Balm, a Species of odoriferous Herb, the little Branch is preſerved more than fifteen days, as green as that of the Garden, and grows a little; whereas it would wither and dry up in a ſhort time, if it did not touch the Water[i]. Therefore it is certain that the nutritive Juice enters into the Plants, both thro' the Roots and Leaves.

Ariſt. But do you believe, *Eudoxus*, that the Sap, in order to its being elaborated more finely, circulates in Plants, as the Blood in Animals?

Eudox. If the ſame Sap aſcends and deſcends, or deſcends and aſcends, it circulates. But 1. The ſame Sap aſcends and deſcends; for when the Stalks of two Yoke-elms join their Barks together in one place, ſo that the Juice of the one paſſes into the other, if you ſhould ſaw the Stalk of the one in the Month of *February*, two Foot below the joining of the Stalks, the lateral Branches, which are below the Union of the Barks, ſend forth ſmall Shoots and Leaves in the Spring, as well as thoſe which are above, and as if they received Nouriſhment from the Roots of their own Stalk[k]. Therefore they muſt receive by the conjunction of the Stalks a Juice, which deſcends from the Branches toward the Roots, after having aſcended from the Roots toward the Branches.

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[i] Mariote des Plantes, p. 82.

[k] Mariote, p. 85, 86.

Accordingly ſhould one meet with a Tree ſupported by great Roots, one of which is uncovered about a foot and an half; let it be cut four Fingers from the Earth, it will periſh, unleſs ſome Juice comes to it which deſcends towards the Roots, after having aſcended toward the Branches; ſince it has no more communication with the Earth. Nevertheleſs the year following it ſends forth both Branches and Leaves[1]. Therefore the ſame Sap aſcends and deſcends.

2. The ſame Sap deſcends and aſcends. M. *Perrault* having pluck'd up many Plants ſimilar and intire with their Roots; took one of them, whoſe Trunk was divided into two Branches, and plunged it into Water only by the extremity of one of them. This Plant continued freſh, while the other were wholly dried up; and the Branch, which was not wet, ſent forth new Leaves.

Conſequently the Sap circulates in Plants; and this is the Opinion of M. *Perrault*, M. *Mariote*, and M. *Malpighi*, Philoſophers of great Knowledge and happy Invention.

Ariſt. In ſhort, Plants have aſcending and deſcending Ducts, which are different from the firſt. And the firſt are deſigned for conveying from below upward, a more ſpirituous and ſubtile Liquor; and the other for conveying from above downward a more aqueous and groſſer Liquor. For, take a piece of a ſmall Elm, without Knots, about three Inches long, and upon each end put a Funnel of Wax; after that, cut the Branch in two, and pour Water into the Funnels. The Water paſſes into the piece of Wood, whoſe Funnel is at the end which was next to the Branches, before they were cut; and conſequently paſſes from the Branches towards the Roots; but without paſſing into the piece of Wood, whoſe Funnel is at the other end, and conſequently without flowing from the Roots toward the Branches. On the contrary, Spirit of Wine is readily diſtill'd thro' the piece thro' which the Water cannot be filtered. Now the Liquor, which goes from the Roots to nouriſh the Stalk, Branches and Leaves, ought apparently to have in aſcending more ſpirituous parts for nouriſhing them. But after it has depoſited its ſpirituous Particles in divers parts, it ought only to bring back from the extremities its more groſs Particles, mixt with the Waters of Vapours, Rain and Dew. Therefore it is probable, that the ſame Liquor aſcends and deſcends, deſcends and aſcends again, in order to convey to the Plants an agreeable Nouriſhment. Probably the ligneous Fibres convey the more ſpirituous Juices toward the Branches; the Utricles bring back the Juices toward the Roots, which are not yet ſufficiently digeſted; and the Tracheæ furniſh Air, which facilitates the Circulation of the Juices.

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[1] Hiſt. de l'Acad. 1709. p.48.

Eud. The Circulation of the Juices at length makes the Flowers and Fruit open. The Action of the Juices ſhoots out the Flowers and Fruit from the Branch, and nouriſhes them by making the moſt elaborate and fineſt Juices flow into their Fibres.

Ariſt. Is the Uſe of Flowers very certain?

Eud. Flowers are ordained to give for a ſhort time a delicate Nouriſhment to growing Fruit, for the Production of the Plant; ſince the growing Fruit periſhes, at leaſt the beſt part of it, when the Aſſiſtance of the Flowers happens to fail. But a particular Converſation upon the Generation, Culture, and Fruitfulneſs of Plants will make us better underſtand the Uſe of the Flowers.

CONVERSATION II.

Upon the Generation, Fruitfulneſs, and Culture of Plants.

Eud. MANY look for nothing more in Flowers than to gratify their Sight and their Smell. The Vertuoſo dwells upon the Smell, Structure and Beauty of the Leaves, and upon the lively Brightneſs and Variety of their Colours. The Philoſopher finds in Flowers qualities more noble, and more worthy to be obſerved. You know, *Ariſtus*, that the Fruit encloſes the Seed, and that the Seed contains a ſmall Plant already formed by the hands of Nature for perpetuating the Species. But will you believe that the Flowers are equally neceſſary for the Production of the Fruit, and for putting the ſmall Plant into a ſtate of budding?

Ariſt. This is a ſort of Paradox, which deſerves ſome Illuſtration. Explain your ſelf upon this Head without any fear of being interrupted. I ſhall find too much pleaſure in hearing you.

Eudox. Flowers, at leaſt the greateſt part, have their Leaves, Calix, Stile, Stamina, and their Summits. The Calix ſerves to encloſe the parts of the Flower. The Leaves of Flowers are parts extended and ſituated round about the Seed. The Piſtillum is a Species of Tube which riſes from the bottom and middle of the Leaves. The Stamina are Threads which ariſe from the bottom of the Flower, round about the Piſtillum, and are terminated by extremities of a different Structure, which are called the Summits *. The Tulip, for example, is compoſed of ſix Leaves, *Fig.* 2. From the bottom and middle of thoſe Leaves ariſes a ſmall hollow Stalk (*a*); this is the Piſtillum. Round this Piſtillum ſome Threads are diſpoſed, very fine, which alſo grow up out of the bottom of the Flower; theſe are the Stamina (*b*). The Stamina end in Extremities bigger than the reſt; and theſe are the Summits (*c*). The Calix is the firſt covering of the eſſential parts of the Flower. The Leaves defend them from the Injury of the Air. The Piſtillum contains in it the Embryo's of the Seed, whereof it is as it were the Ovarium. The Summits of the Stamina are Capſules or Veſicles, which in their maturity open and ſend forth a Duſt of different Configuration, according to the difference of Plants. This being granted, if it is the Duſt of the Summits which makes Plants fruit-

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* Mem. de l'Acad. 1711. p. 210.

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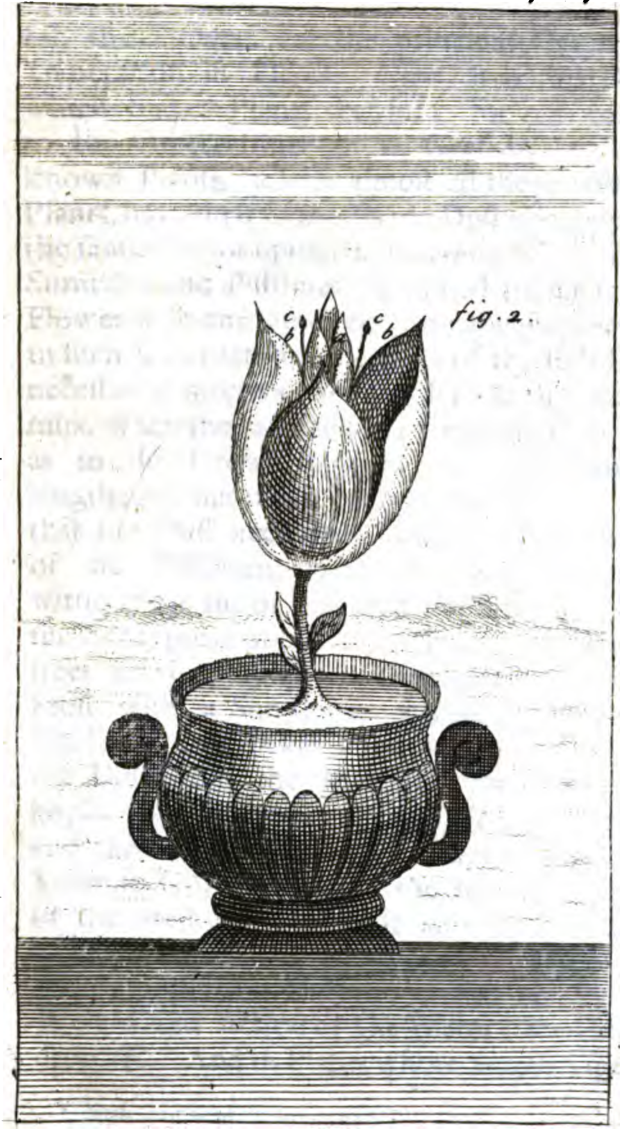
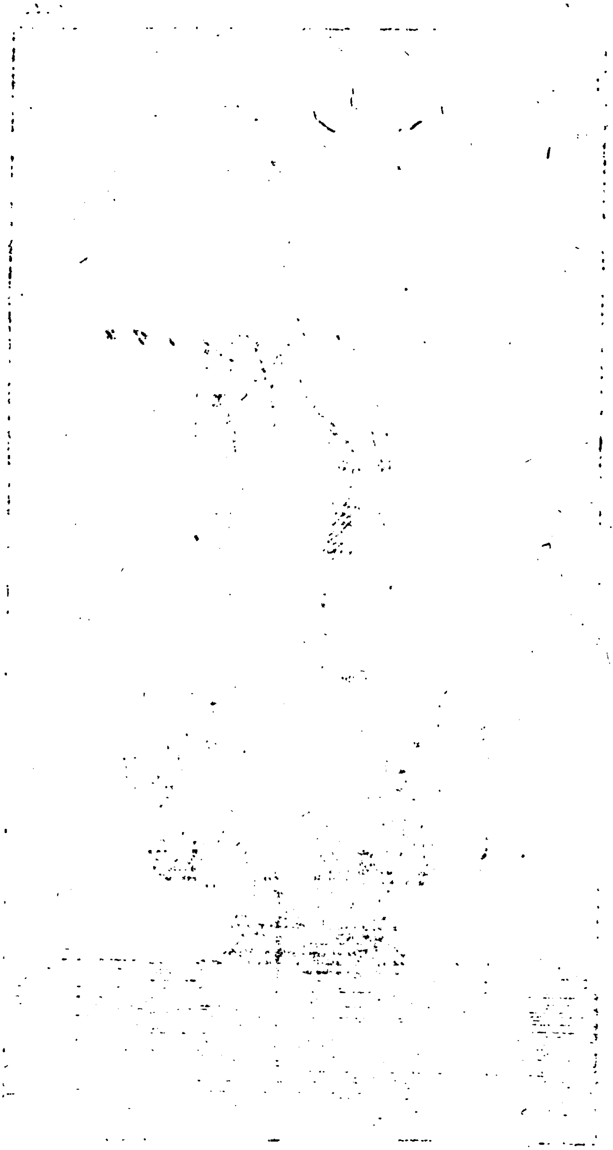


fig. 2.



ful, the Flowers are the principal Organ of Generation in Plants. Now, it is this Duſt which makes Plants fruitful; for according to the Obſervations of M. *Geofroy*, 1. The known Plants, at leaſt almoſt all the terreſtrial Plants, have their Summits and Duſt either upon the ſame foot or upon ſeparate ones *. 2. The Summits and Piſtillum, if joined in the ſame Flower with the ſame Foot, are always ſituated in ſuch ſort, that the extremity of the Piſtillum neceſſarily receives the Powder of the Summits, when they are faded. In bending Flowers, as in the Crown-Imperial, the Piſtillum is lengthened out much beyond the Stamina, ſo that the Duſt neceſſarily covers the extremity of the Piſtillum, when it falls. Finally, without the aid of this Duſt the Embryo's of the Seeds prove abortive [a]. Thus when Fruit-trees are in bloſſom, if there comes a white Froſt with a Sun-ſhine, which dries up the Piſtillum, and makes it incapable of receiving the Duſt from the Summits, the Gardener's hopes are fruſtrated. If the Corn bloſſoms, and the Mildew or Rain corrupt or make the Summits fall, the Cells of the Seed are empty, or the Seed unfruitful. If an exceſſive Rain happen during the bloſſoming of the Vine, the Summits and Duſt are carried off by the Weight and Action of the Water; the Grapes drop off. And in Plants whoſe Stamina ſpring up on the ſame Pedicle, if one cut thoſe Stamina before the Summits are open, the Fruits do not come to maturity; or if they ripen, they are barren [b]. Therefore the Flowers are the principal Organ of Generation in Plants.

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[a] Mem. de l'Acad. 1711. p. 223.

Ariſt. But how ſhall we accommodate this Hypotheſis to thoſe Plants, of which one Species bears Flowers without Fruit, and the other Fruit without Flowers; and of which ſome bear Stamina and Summits upon a different Pedicle from thoſe which bear the Fruit?

Eud. The Duſt of the one goes to impregnate the Seed of the other, ſeparated and often very diſtant. Hence the Male and Female Plants. The Plants which only bear Flowers, and make the other fruitful, are called Male Plants. Thoſe, which only bear Fruit, and are made fruitful by the firſt, are called Female Plants. Has the Female Palm no Male in its neighbourhood, at leaſt for ſome diſtance? It bears no Fruit. If it bears any, they do not ripen, they are of a bad Taſte, without Kernel [c] and without Burgeon; therefore they take care to plant a Male Palm near the Female, or to cut ſome Branches of the Male Palm charged with ſome faded Summits, and faſten them over the Branches of the Female ones. And then the Female

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[b] Mem. de l'Acad. 1711. p. 225.

[c] Mem. de l'Acad. 1711. p. 226.

Palm bears teeming Fruit in abundance, and of a good Taſte.

Ariſt. But what is the Vehicle of the Duſt of one Pedicle to the Fruit of another?

Eud. The agitation of the Air or the Wind. A remarkable Fact is a ſufficient good Proof of it. If we credit a Poet upon this head, two Palms have been obſerved diſtant from one another more than fifteen Leagues, the Male at *Brindes*, the Female in the Wood of *Ottrante*. The Female Palm of *Ottrante* was many years without Fruit: But whenever it had lifted up its Head above the other Trees of the Foreſt, and could ſee the Male at *Brindes*, it became fruitful, and begun to bear Fruit of a good Taſte and in plenty [d]; probably becauſe then it begun to receive the Farina, which the Wind brought from the Stamina of the Male Palm, upon the Embryo's of its Fruit, over the other Trees. Is it not natural to think that the Wind and Duſt of the Stamina had more ſhare in this marvellous Event, celebrated in Poetry, than the Love and Sympathy of Trees of different Sexes?

Ariſt. Therefore, *Eudoxus*, the Powder of the Stamina, which is ſulphurous, and compos'd of ſubtile and penetrating Particles, as the Scent ſufficiently ſhews, falling upon the Piſtillum, which contains the Fruit, muſt be diſſolved; muſt penetrate the Subſtance of the Piſtillum and Fruit, and at length cauſe a Fermentation capable of making the little Plant contained in the Seed unfold and bud.

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[d] Mem. de l'Acad. 1711. p. 228.

Eud. This ſeems to be the Principle both of the Generation and Fruitfulneſs of Plants. Fruitfulneſs is ſtill a Wonder ſufficiently expoſed to our ſight, without having been hardly ever obſerved: which yet did not eſcape the Obſervation of M. *Dodart.* He choſe an Elm of ſix Inches diameter, twenty Inches high to the ſhooting out of the Branches, and which might be twelve years old. He cauſed a Branch of it eight Foot long to be pulled down. Upon this Branch were found 16450 Seeds[e].

This being granted; as there are no new Seeds formed[f], a Tree of this kind really contains at leaſt fifteen Billions eight hundred and forty Millions of Seeds, very diſtinct and ſeparate from one another; without counting thoſe, which each Seed may contain; and conſequently wherewith it may produce itſelf a-new ſo many times.

Wonderful Source! For in a word, an Elm of ſix Inches diameter, has at leaſt ten Branches of eight Feet; and theſe contain 164500 Seeds. The other Branches taken together may bear as many Seeds, and ſo there will be in all the Branches 329000 Seeds.

The Age of twelve Years is not that of the common Fertility of the Elm: we may allow it 330000 Seeds for its Fertility, taking one year with another. This Elm may for an hundred years bear 330000 Seeds every Year. The 330000 Seeds muſt be multiplied by the hundred years of fecundity; and that will be 33000000 of Seed. Lop the Elm, the Extremity of the Trunk that is lopt will ſend forth as many Shoots or Branches as it had, in the ſpace of about ſix Lines in height. In whatever part one lop it, it will always ſhoot forth equally, as appears from Dwarf-trees, which are cut almoſt level with the ground. Conſequently if you divide the Trunk from the ground to the growth of the Branches, into circular Rings ſix Lines high, every Ring ought to contain as many inviſible Branches, and in thoſe Branches as many Seeds, as the Branches which appear: wherefore this Elm contains as many times 33000000 of Seed, as ſix Lines of height are contained in the height of twenty Foot. Therefore there are in the Elm 15840000000 of Seed. What do I ſay? Each Seed contained in the Elm, does it ſelf contain an Elm, which contains the ſame number of Seeds. Therefore the Elm contains 15840000000 of times fifteen thouſand Billions 840000000 of Seeds. Every Seed of theſe fifteen thouſand Billions contains as many, and ſo forth.

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[e] Hiſt. de l'Acad. 1700. p. 65. Memoire 1700. p. 155.

[f] 1 Converſation. T. 3. p. 6.

Ariſt. I muſt acknowledge, *Eudoxus*, Reaſon conducts the Imagination thus far in this immenſe Calculation. But at laſt, both Reaſon and Imagination find themſelves as it were loſt and ſwallowed up in an Abyſs.

Eud. After all, is it ſurprizing that Power and Wiſdom without bounds ſhould have every where ſpread traces of Infinity? Certainly we ſee them in the fertility of Plants. But why muſt a great number of Trees be grafted in order to produce good Fruit?

Ariſt. I ſhall ſoon ſee the Reaſon of that in your opinion concerning Grafts.

Eud. To graff or to inoculate a Tree, is to inſert in it a Graft or Shoot of another Tree, ſo that the Graft and the Tree grafted may become one and the ſame Plant. They inoculate after ſeveral methods. To inoculate by cleft, is to cleave the Tree which one inoculates, and to place the Graft in the Cleft. To inoculate in the Bark, is to put the Graft between the Bark and the Wood. To graff by Scutcheon, is to remove from off a Tree a Scutcheon or Shoot, with a great part of the Bark, out of which it riſes, and to apply it upon another. They make a ſort of Covering to the Wounds of graffed Trees, not only to hinder the action of the Air upon the Wounds, leſt it ſhould dry up the Fibres, and render them incapable of tranſmitting or receiving the nutritive Juice; but that the nutritive Juice aſcending abundantly in the Spring, may be ſhut up from a poſſibility of diſſipating, and conſtrained to ſwell the Veſſels of the Graft, which it finds open. The Juice, by virtue of its paſſing from the Trunk into the Graft, unites them at laſt in one and the ſame Plant.

Ariſt. But why does the Graft bear the ſame Fruit, and Fruit of the ſame Taſte, as the Tree from which it proceeds?

Eud. Becauſe the Fruit is produced from the Graft, which received its Seeds from the Tree out of which it was taken; and becauſe the Juices, which flow thro' the Fibres of the Graft, do therein take a Configuration conformable to the Graft; and to the Tree which produced it.

Ariſt. The Fruit of the Graft is better.

Eud. The Juice, which nouriſhes it, is better prepared; becauſe it is fermented and ſubtilized, not only in the Trunk, but in the Graft, whoſe Texture is different, more compact, or more proper for purifying the Juice.

Ariſt. Finally, graffed Trees are generally more fertile than others.

Eud. Becauſe they commonly make choice, for graffing, of Sets, whoſe Roots being more extended, receive more Juice. Beſides the Juice which is filtred thro' the Grafts, being more pure, is alſo more proper to nouriſh and bring forth the Fruit.

Culture contributes to the Fecundity of Plants proportionally as it prepares and diſtributes the nutritive Juices. When you would have the Scutcheons cover the Wall the ſame Year, and leave no Vacuity in the Eſpalier, you muſt pull off the Bloſſoms, that ſo the Sap not being employed in nouriſhing either the Bloſſoms or Fruit, may afford the more to the Branches. If the Branch of the Scutcheon has ſhot out to the length of eight or nine Inches, it is good to nip it at the end, becauſe the Sap being ſtopt by the extremity which is nipt, dried up, and incapable of accretion, will cauſe a great number of ſmall Branches to ſpring out, which will bear plenty of Fruit the following Year *.

Are you willing, *Ariſtus*, that on the firſt Opportunity we talk of ſeveral curious Plants, both marine and terreſtrial; of Coral for example, Muſhrooms, Gin-ſeng, the Coffee-tree and ſenſitive Plant?

Ariſt. If you will explain yourſelf upon the Coral, Muſhrooms, and Gin-ſeng, I will reſerve the Coffee and ſenſitive Plant for my ſelf.

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* Mem. de l'Acad. 1716. p. 199.

CONVERSATION III.

Upon the Plants of the Sea, Coral, Muſhrooms, and Ginſeng.

Eud. YOU would have me then, *Ariſtus*, explain myſelf upon the Plants of the Sea, and particularly upon Coral, Muſhrooms and Ginſeng.

1. As the Sea has its Animals different from the Land, it has alſo its Plants different from thoſe which the Land produces. Amongſt the marine Plants, ſome have Leaves, and others none. The greateſt part have no apparent Roots, and come up on hard Bodies, ſuch as Rocks and Shells to which they are attach'd by a ſmooth and poliſh'd Baſe. Theſe Plants without Roots, may paſs for Roots in their whole Subſtance; that is to ſay, organized after ſuch a manner, as to attract Aliment on all ſides by an infinity of Pores. In ſhort, marine Plants are on all ſides ſurrounded with the Water of the Sea, which nouriſhes them; and ſo far as M. *Marſilli* could obſerve with a Mi-

Microſcope *, they are only a collection of ſmall Glands which filter the Sea-water, and ſeparate from it the lacteous and glutinous Juices, in order to nouriſh themſelves therewith.

There are ſtony Plants in the Sea, as the Corals. Coral ordinarily grows attach'd to the upper part of a Cavern, with the Branches downward, contrariwiſe to Land Plants. It is equally hard in the Water and out of it. What proves the Coral to have been a Liquid in its firſt formation, is, that ſometimes it covers the inſide of a Shell. The Surface of the Coral being ſtript of its Bark, is all furrow'd with Channels which reach the extremity of the Branches. The extremity of the Branches of Coral is inflated, formed round, and contains ſome Lodges full of a ſharp, cauſtic and viſcous Milk. This Milk running out of its Lodges, and falling into the Water, without being mixt with it, is attach'd to Bodies which it encounters; and probably faſtens to them a very minute Plant, which being open'd, diſcovers at firſt a reddiſh Point, as M. *Tournefort* conjectures, and then a Coral Plant [a]. The Coral has its Flowers; a Diſcovery which we owe to Count *Marſilli*. They are white. Every one has its Pedicle and eight Petals. Theſe Flowers ſpring out of all the ſmall Tubes of the Bark. Draw the Plant out of Water; the Flowers enter again into the ſmall

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* Hiſt. de l'Acad. 1710. p. 72.

[a] Hiſt. de l'Acad. 1700. p. 35.

Tubes. If you put it again into Water, you ſee it bloſſom a-new in leſs than an Hour. Sometimes for the ſpace of twelve days it is contracted and blown as often as one pleaſes [b]. After which, its Flower falls to the bottom of the Water in the form of a ſmall yellow Ball.

2. The Muſhroom is one of thoſe Land-Plants that are moſt curious in the eyes of Philoſophers. The Method by which they make it grow up at *Paris* is ſingular enough, as we have already obſerved. In order to have of it all the year, they make two ſorts of Beds, the one in Gardens, and the other in the Fields. Thoſe afford Muſhrooms from *All-ſaints* to the end of *April;* and theſe from the Month of *May* to the earlieſt Froſts [c]. Theſe Beds are made with Horſe-dung. To make thoſe in the Gardens, they heap up the Dung in the Month of *June.* In the Month of *Auguſt* they ſpread it out to the height of a Foot upon the places where they have a mind to make the Beds. They water the Dung for five or ſix days, according to the drought of Summer. After having wetted it, they turn it over with a Fork that ſo it may imbibe the Water. After this preparation, they make the Beds with three Lays. Theſe Lays are prepared fifteen Days, or three Weeks, one after another. The firſt Lay has two Foot and an half in

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[b] Hiſt. de l'Acad. 1710. p. 76.

[c] Mem. de l'Acad. 1707. p. 58.

breadth, and one Foot and a half in height. And if the Seaſon is too dry, they wet this Lay every day.

Toward the middle of *Auguſt*, with the ſame Dung which they uſed for the firſt Lay, they raiſe up the ſecond with a ſharp Ridge, to the height of one Foot above the firſt. They wet it. They trim the height again handſomly, and this reparation they call the third Lay.

The Paths which are between the Beds, are five or ſix Foot broad. They cover theſe Beds with Mould, which has been uſed for Beds of Melons. They lay it about the thickneſs of an Inch. To make Muſhrooms come up ſpeedily and in abundance upon theſe Beds, they ſink into them a Foot deep, and three Foot diſtant from one another, upon the ſame Line, pieces of a Dunghill as large as one's Fiſt, prepared and thrown up together in the Month of *February*. When they have ranged theſe Parcels of Dung in the Bed, they cover it with Mould. Over the Mould they place ſome freſh Litter juſt taken from under the Horſes. After this they touch the Beds but every eight Days. Are they cool'd? They muſt be covered with freſh Litter. If it freezes, to divert the Froſt they immediately cover the Mould with dry Dung, and over this Dung they put wet Dung. If the Beds ſmoak too much, they leave only a half covering of Dung. When the Muſhrooms begin to ſpring up, the

Dung grows white; one ſees it beſtrewed with ſmall white Threads, fine, ramous, and twiſted about the Straw, whereof they are formed. The Dung no longer retains its ſmell, but diffuſes the Scent of Muſhrooms. Thoſe white Threads are probably the Burgeons of the Muſhrooms. The extremity of thoſe Threads is formed round, and becomes a Button, which encreaſes by little and little. M. *Marchand*, a skilful Botaniſt, preſented the Academy of Sciences with a view of the firſt formation of Muſhrooms in mouldy Horſe-dung[d]. They begin to gather Muſhrooms in *October*, and this gathering is generally made every third or fourth day.

They raiſe the Beds in the Field in the Months of *November* and *December* with freſh Earth; that is, ſuch as has not produced Muſhrooms for a long time. Theſe Beds commonly afford Muſhrooms from the Month of *May* to the earlieſt Froſts. The lower part of theſe Muſhrooms is a Pedicle bearded in that part which is ſunk into the Earth, and bearing on the other end a ſort of round Head in the form of a Cap. The upper part of it is ſpread out into Rays, and the Laminæ which paſs from the Center to the Circumference, are as it were the Leaves of the Muſhrooms. I don't know whether you will believe what they tell us, that in the Confines of *Hungary* and *Croatia* there grow Muſhrooms of ſuch a prodigious ſize, that one alone would load a Waggon [e].

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[d] Hiſt. de l'Acad. 1678. p. 169.

3. The Ginſeng is a precious Plant, very rare, and much ſought after, for the ſake of the Root. The Root of it is commonly forked into two pretty large Branches, like the two Thighs of a Man. And thence comes the Name of Ginſeng, which in *Chineſe* ſignifies *the Thighs of a Man*, or ſomething reſembling them [f].

The Ginſeng has excellent Vertues; It revives the natural heat, gives motion to a feeble Pulſe, purifies the Blood, and fortifies the Stomach. Thus according to the Expreſſion of the *Chineſe*, it is the ſpirituous Simple, the pure Spirit of the Earth, a Receipt for Immortality. Father *Jartoux*, a Jeſuit, a Miſſionary to *China*, ſaw a body of ten thouſand *Tartars* gathering Ginſeng in *Tartary* that is ſubject to the Emperor of *China*. This Monarch buys it at the weight of fine Silver, and ſells it again four times dearer in his own Dominions, where it is ſold only in his Name. Father *Joſeph Lafiteau*, the Jeſuit, found it in *Canada*. This wonderful Plant is ſcarcely found any where elſe, but in the Foreſts of *Canada*, and thoſe of *Tartary*. The miſſionary Jeſuits have in their Travels met with two choice Plants, the Ginſeng and Quinquina or Jeſuit's Bark.

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[e] Journ. des Sçav. 1678. p. 176. 2 May.
[f] Hiſt. de l'Acad. 1718. p. 41.

You are now, *Ariſtus*, to deſcribe me the Coffee-tree, and teach me after what manner, and upon what principles a Philoſopher extracts an excellent Liquor from the Fruit of this Tree.

Ariſt. In the Royal Garden of Plants a Tree may be ſeen of this Species, between five and ſix foot high, and an inch thick. The Branches of this Tree ſpring out from ſpace to ſpace, the length of its Trunk, continually oppoſite by two and two, and ranged in ſuch ſort that one Pair croſſes another. In all Seaſons they have their Leaves entire; ſharp at the two ends, oppoſite by two and two, pretty like thoſe of the Laurel, but ordinarily larger and ſharper; of a comely green, gay and bright upward, of a pale green downward, of a yellow green in their growth, waved in the edges; having two inches or more in breadth, above four or five in length, and their Stalks very ſhort.

From the wing of the Leaves, Flowers ſpring up of a ſweet and agreeable Odour, each of them ſupported by a very ſhort Pedicle; all over white; with white Stamina and yellow Summits, diſpoſed round about a forked Stile, which ſurmounts the Embryo or young Fruit, placed in the bottom of a green Calix.

The young Fruit is green, clear at firſt, then reddiſh; after that of a fine red, and laſtly, obſcure when ripe; of the Bigneſs and Figure almoſt of a hard Cherry. The Pulp which encloſes it has two Shells, minute and oval. Each contains a Seed oval and vaulted on one ſide, and flat, hollow or furrowed on the oppoſite ſide, where the two are joined together. They call *Coffee in the Shell*, the whole Fruit being dried; and *cleanſed Coffee*, the Seeds ſtript of their Covers. The Coffee of the Royal Garden has the ſame Taſte as that which is brought from *Arabia* [g].

The Coffee-tree grows in *Arabia* toward the Road of *Moka*, to the height of 40 foot; while the Diameter of its Trunk does not exceed four or five inches. It is ſeen almoſt continually in bloſſom, and bears Fruit two or three times a year.

The Seed of the Coffee-tree ought to be put into the Earth quite freſh, if poſſible, as M. *Juſſieu* has obſerved in the Royal Garden. This Plant has multiplied. It has ſpread into divers Countries. It has reached as far as into *America*. *Caienne* has its Coffee.

The uſe of Coffee is common in *Turkey*, *Perſia*, *Armenia* and *Europe*. For roaſting it, Veſſels of varniſhed Earth are more proper than thoſe of Iron or Braſs; becauſe the laſt may communicate to it the impreſſion of Iron or Braſs. A Sign of its being roaſted to a due degree, is its Colour inclining to violet. Would you make the Infuſion or Liquor of it as agreeable and profitable as poſſible, you muſt powder it the very moment you have a

[g] Mem. de l'Acad. 1713. p. 294.

mind to infuſe it; and you muſt infuſe it in boiling Water, becauſe it then loſes leſs of its volatile Salts that are piquant and capable of pleaſing the Taſte, and agitating the Blood. Thoſe Salts are probably the Principles of its ſpecial Virtues.

Eudox. The principal Virtues of Coffee are, as I think, without ſpeaking of the Taſte, to facilitate Digeſtion, cure the Hypo, diſſipate Humours, prevent Drowſineſs, keep one awake, render the Ideas diſtinct, and to confirm the Memory. One may give credit to Orators on this head.

Ariſt. Coffee contains volatile Principles, both ſaline and ſulphurous, if one judge of them by the oily matter which appears upon the ſurface when one roaſts it, and by the Odour which it diffuſes. Theſe Principles are probably the ſource of the Virtues which you attribute to it. The Salts ought to inciде the Victuals, and by that means facilitate Digeſtion. The mixture of the Salts and Sulphurs in the Blood cauſe Fermentations, which open the Veſſels, and cauſe obſtructed Humours to flow. Hence the Hypo and Drowſineſs are diſſipated. Finally, the ſpirituous Particles, which ariſe as far as the Brain, agitate it, and agitate the Traces to which the Ideas are attach'd. This Agitation inceſſantly preſents new Ideas to the Mind; and hence proceed waking, and diſtinct Ideas.

The Senſitive Plant of the Royal Garden has ſomething in it that touches me ſtill more. Would you not ſay that this Plant has ſome Senſation, and that it deſerves the Name which it bears? Whenever the Finger ſeems to be upon the point of touching it, the Leaves contract themſelves, fall down upon their Branches, and the Branches upon the Stalk. The Plant is contracted, and in vain ſhould you attempt to extend it, or reſtore it to its former figure by touching it; it would ſooner ſuffer it ſelf to be torn to pieces.

Eudox. Is it a ſort of Baſhfulneſs then which contracts it, and keeps it ſo obſtinately contracted?

Ariſt. When one approaches it with the Hand, there iſſue Spirits out of the Finger by Tranſpiration. Theſe Spirits penetrate the Fibres of the Plant, interrupt the Courſe of the Juices, and ſtop their Circulation. The Circulation of the Juices being ſtopt, there are Fibres which ſwell and ſhrink. This ſhrinking contracts the Plant. And this ſeems to be the Principle of the Senſibility of the Senſitive Plant.

Eudox. The Senſitive Plant has ſomething extraordinary in it; but according to the Journals of the Learned, *Germany* is fertile in Plants much more curious[h]. They have gathered there Morilles which they could ſcarcely cut by reaſon of the Particles of Silver which they contained. They have ſeen a Rod of Silver growing in a Wood, and a ſilver Wand iſſue out of a Rock. Gold has been found in the Pith and Veins of Trees. What do I ſay? They have ſeen Gold it ſelf riſe out of the Earth in ſmall Threads, and twiſt it ſelf round about the Vine; in a Field of Oats they reaped Ears of Metal, wherewith they preſented the Emperor *Rodolphus*.

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[h] Journ. des Sçav. 17 May 1683. p. 143.

Ariſt. Theſe Phenomena, I think, are too ſingular to be probable. Could the Juices deſtined by Nature to form the moſt precious Metals, have been thruſt by the Fermentations of the Earth into the Tubes of Plants, and have taken the figure of them before they were hardened; or could the metalline Particles, already formed, aſcend into the Plants, as ordinary Juices, in order to aſſume therein different figures of Plants, by uniting themſelves to one another in Tubes differently turned? The Plants have probably Particles of Iron, ſince with a Loadſtone they find Particles of Iron in the Aſhes of Plants; and it is affirmed that a Brook in *Hungary*, changes the Leaves of an Oak into Leaves of Copper, which continually preſerve their former figure of the Leaves of an Oak[i]; becauſe the metalline Particles, which penetrate the Leaves of Oak, are united to them, and diſpoſed according to the texture which they find in them.

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[i] Journ. des Sçav. 6 Fev. 1679. p. 36.

Eudox. The Idea of Leaves brings to my mind both the *Enſeté* and *Tallipot*. "I ſaw in "*Abiſſiny*, ſays a Miſſionary [k], a Tree which "they call Enſeté. Its Leaves are ſo large, "that two of them are ſufficient to cover "a Man both behind and before. They hang "Rooms with them, they make uſe of them "for Carpets, for Napkins, and Towels; "and the green of them is very fine. They "grind the Branches or thick Ribs of the "Leaves, and reduce them into a very fine "and white Meal, which being ſoak'd and "boil'd with Milk, is delicious Food; the "Trunk and Roots are more nouriſhing "than the Branches. They cut the Trunk "into pieces like Turnips, and boil them with "Meat. Oftentimes the wealthy themſelves "eat them by way of Regale. The *Abiſſines* "ſay, that when one cuts this Tree, it utters "ſighs; and when they would ſay that they "are going to cut an Enſeté, they ſay we "are going to kill an Enſeté. This Tree "bears on its top a long Pod, which contains "five or ſix hundred Figs."

The *Tallipot* [l] is a Tree which grows in the Iſland of *Ceilon*. Is is of the height and thickneſs of a Maſt of a Ship. The Leaves of this Tree have ſomething in them ſtill more aſtoniſhing than that of the Enſeté. They ſay that the Leaves of the Tallipot are ſo large, that one of them alone may ſerve to cover fifteen or twenty Perſons together.

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[k] Father *Lobo* J. Hiſt. Relat. of *Abiſſiny*, p. 113.

[l] Mem. de Trev. May 1703. p. 860.

Ariſt. On the contrary, the Leaves of the Tea are very ſmall [m]. The Tea is a large Shrub, much like our Roſe-buſhes. It bears white Flowers, ſomething like wild Roſes. The Stalk and Branches of this Shrub are from the earth to the top covered with a prodigious number of Leaves, ſmall, ſharp, dented, and of five different ſizes. The Leaves fartheſt diſtant from the Earth are the ſmalleſt, and in proportion as they diminiſh in ſize, they augment in value.

Eudox. A Plant valuable and famous in all ages is the Cedar [n]. The Cedar is a Tree which reſembles the Fir-tree, always green. Probably the compact texture of its Leaves preſerves their Juice in the middle of Winter *. The Gum flows down from the Cedar. It is a ſudorific Gum; and the *Egyptians* make uſe of it in embalming their dead, to give their Corpſes, even after death, a ſort of Immortality, which Nature beſtows on the Wood of the Cedar.

The moſt precious and ſingular Plants have Maladies, as Animals have, in the courſe of their Vegetation. Let us make the Diſeaſes of Plants the Subject of our next Converſation.

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[m] Rep. des Lett. Fev. 1685. Tom. 3. p. 207.

[n] Mem. de Trev. May 1703. p. 862.

* As Oil is an excellent Preſervative againſt the Injuries of cold, ſo it is found to abound in the Sap of the more northern Trees; and it is this which in Ever-greens keeps their Leaves from falling. *Hale's vegetable Staticks.*

Conversation IV.

Upon the Maladies of Plants.

Ariſt. WHAT are the Maladies of Plants; and whence do they proceed? I wait, *Eudoxus*, your opinion upon this head.

Eudox. Plants are indiſpoſed, when an agreeable Juice is not diſtributed into their different parts. In that caſe you ſee them languiſh: Theſe Languours have ſeveral cauſes, namely, the exceſs or defect of the nutritive Juices, the Malignity of theſe Juices, Fertility itſelf, and external Accidents.

1. The Exceſs of the nutritive Juices burſts the Veſſels, and produces dangerous Effuſions: Should the exceſſive Juice become grumous in the Tubes for want of Velocity, or Space to flow in, it will be ſtopt. The Juice which continually aſcends from the Roots, penetrates and gradually poſſeſſes the Tracheæ, which are as it were the Lungs of Plants, and hinders the Commerce and Action of the Air. The Circulation is intercepted and the Plant dies as if it were ſuffocated.

2. The want of Juice produces the ſame effect. A great quantity of Juice is loſt by Tranſpiration, as is obſerved in Plants, which ſink down during the heat of Summer. If none comes from the Roots to repair this loſs, the Fibres being deſtitute of Humours, are contracted, loſe their Agitation, are dried up, and become incapable of receiving new Juices; the Plant languiſhes and dies. The Leaves grow yellow, wither and fall, when the Plant no longer furniſhes them with a Juice delicate enough, and ſufficiently prepared, to be filtered thro' their Fibres.

3. The Malignity of the Juices cauſes theſe Languours and the death of Plants, by corrupting the Organs. Urine, for example, Lime-water, the Water of a Dunghil, a little too ſtrong, and Beds too hot, burn up the Fibres of the Roots, by the exceſs of their corroſive Salts too much agitated, and put them out of a condition of receiving and filtering the Juices of the Earth. Is the Juice too viſcous? It imbibes, thickens and fixes. It cannot flow, nor afford motion enough to the young Embryo in order to open it; and the Plant, far from bearing Fruit, periſhes for want of nutritive Juice, which brings life into its Fibres, Stalk, and Branches.

4. The Fertility it ſelf of Plants is ſometimes a cauſe of their Maladies. Giving too much Juice to their Fruit they don't preſerve enough for nouriſhing themſelves. Accordingly

ly Trees too fertile are of leſs duration than others.

5. The external accidents which cauſe the Maladies of Plants are Inciſions, Froſt, Heat, Hail, the nipping of Inſects, paraſitical Plants, &c.

Inciſions are hurtful, and even mortal to Plants, if one cut the Roots, or ſtrip them of their Bark, or otherwiſe break the Wood; ſo that no more remain but the Bark; becauſe in that caſe the Sap can no longer convey nouriſhment into the different parts of the Plant.

Froſt, which dilates the Juices, as it dilates Water in Veſſels which it breaks, tears aſunder the Fibres of Plants, cleaves the Trees ſometimes, and ſhivers them.

Heat violently agitates the Juices, and attenuates them; opens the Pores of Plants, and preſſes the Juices out of them by the exceſs of Agitation. The Fibres being deſtitute of Juices, are relaxed. The Plants without any force are preſſed down by their weight, and languiſh.

The Hail bruiſes the Fibres of the Leaves, and extravaſates the nutritive Juices. But why is Hail leſs pernicious when Rain falls at the ſame time?

Ariſt. Rain ſoftens the Fibres, renders them more flexible, and conſequently fitter to eſcape the violence of the Hail by yielding.

Eudox. As for the nipping of Inſects, it produces Tumours upon Plants. Theſe little Animals nip certain parts of Plants, and depoſite their Eggs in them. The nipping is followed by an effuſion of nutritive Juice. This Juice being ſhed, penetrates the adjacent Pores, where it is gathered into a Maſs, dilates the Fibres, enlarges and puffs up the Pores, in the middle of which the Egg is at laſt hatched; and it is a Worm, or a Fretter, which finds its Nouriſhment already prepared in the Tumour. Hence theſe Species of Veſicles upon the Leaves of Elms, Gall-nuts, and the Grain of Scarlet.

The ſmalleſt Gnats attack the biggeſt Trees. They nip the Leaves of Elms, and therein depoſite their Eggs. The Juice, whoſe ordinary courſe is interrupted by the nipping, is extravaſated and produces Veſicles, ſometimes as large as the Fiſt, and full of a Balm, in which one may ſee greeniſh Fretters floating, which have come out of the Eggs, but excellent for Wounds.

Gall-nuts are formed after the ſame manner upon the Leaves of the Oak.

Whence proceeds the Grain of Scarlet *? A kind of ſmall Scarabæus, covered with a very fine Down, being attach'd to the Branches of the Scarlet Oak, which they call Kermes, and which is found in hot Countries, nips the Leaves near the Pedicle, and depoſites in the nipping the Egg of a Worm, which at laſt produces a ſmall Fly. The Juice being ſtopt by the nipping, and by the Egg, ouzes out. A Tumour ariſes. The Tumour forms Grains of about two Lines diameter. Theſe Grains are filled with a Subſtance of a very lively red, which encloſes the Egg; and this red makes a Crayon of Scarlet.

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* Mem. de l'Acad. 1705. p. 339.

The paraſitical Plants are often more pernicious than the nipping of Inſects. They call paraſitical Plants certain Plants which live only upon the expence of others, as the Moſs and Miſletoe; for theſe are true Plants, and the Roots of theſe Plants are graffed into the Bark of Trees, draw Juice out of them, and rob them of their Sap for their own Nouriſhment; and by that means weaken, exhauſt, and oftentimes deſtroy them.

The Mouldineſs itſelf, which comes upon Plants, ſhut up in damp Green-houſes, is ſome ſmall paraſitical Plants, of the Species of Moſſes and Muſhrooms, which the moiſture cauſes to ſpring out in the Net-work of the Bark. Would you believe that things which appear mouldy, are as it were ſo many Meadows enamell'd with Flowers?

A Virtuoſo * affirms, that with a Microſcope he ſaw diſtinctly, in a ſpot of Mouldineſs, upon the Cover of a Book, Flowers, ſome in Buttons, others blown, and ſome wholly in Flower.

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* M. Hook Microg. J. des Sçav. 20 Dec. 1666. p. 499.

The Seeds of paraſitical Plants are extremely ſmall; and the Winds convey them caſually upon Walls, Roofs and Trees, where being favourably depoſited, they grow up.

Ariſt. Muſt all theſe Maladies, *Eudoxus*, be without Remedy?

Eudox. Many Maladies of Plants have their Remedies, as thoſe of Animals. Inciſions, for example, ſometimes diminiſh the exceſs of Juices. They move the Earth which covers the Roots; they let in more Air by moving it, and likewiſe cover it with Dung. A greater abundance of Juices penetrates to the Roots; the Air makes it enter by the action of its ſpring; and by that means they cure the defect of the Juices.

If the Roots become rotten, Cow's or Hog's Dung puts a ſtop to it. Are they mouldy? They waſh them with clear Water, which tears and carries off the ſmall Threads of Moſs that are growing up. When a ſort of Slime relaxes the Fibres, and cauſes Obſtructions capable of making the Leaves fall off, Mould and Pigeon's Dung produce Fermentations and furniſh Salts which unſtop the Fibres, reſtore them to their former ſtrength, and remedy the evil.

If ſome viſcous Juices render Olive or Orange-trees ſlow, Hen's or Dove's Dung, Vine-aſhes, and Lime itſelf being mixt in Autumn with the Earth, which covers the Roots of thoſe Plants, afford Juices more fluid and efficacious, and haſten the Flowers and Fruit.

To avoid Mouldineſs, they keep the Green-houſes very dry. The Plants themſelves which come out of hot Countries, are preſerved during the ſevereſt Winters, in Boxes well glazed, and not much higher than the Plants. They ſtore the bottom of theſe Boxes with Dung. They let freſh Air into them, while the Sun is in his force: this is always a dry Air without Moiſture, which does no hurt to the Plant.

The Wounds of Trees are not always without Remedies. If by chance the Branch of a Tree is half broken, and the Bark be not wholly ſeparated from it, they draw the two parts of the Branch together again, and make an apparatus capable of ſtopping the Sap, and of hindering the Air from drying up its Moiſture, or from making any alteration in it. The Sap either finds, or makes itſelf free paſſages again, and the Branch recovers.

Are you now willing, *Ariſtus*, after having examined the Principles of Botany, that we try which ſhall explain the moſt Problems in it?

Ariſt. I accept your Challenge; but ſhall be well pleaſed firſt to recollect what you have ſaid to me concerning Plants. To-morrow at three of the clock after Dinner, I ſhall wait on you in the Phyſick-Garden.

CONVERSATION V.

Wherein is explained a great number of curious Facts and Problems, which relate to Botany.

Eud. FOR what uſe does it ſerve, *Ariſtus*, to move, dig, labour, dung and dreſs the Earth ſo much?

Ariſt. The Earth being prepared after that manner, has thereby the more Interſtices, proper for tranſmitting the Rain, Vapours, and Nouriſhment to the Roots; more Salts diſengaged and fit for fermenting and furniſhing Juices; and more Air fit for ſeconding the Fermentations in the Earth by the action of its Spring, and for making the Salts and Water enter into the Fibres of the Roots.

Eudox. Whatever facilitates the opening of the Seeds by its Action, cauſes or haſtens the growth of Plants. Hence divers Secrets of Agriculture, of which the Journals of the Learned make mention.

1. If we burn or calcine Earth, and after that water it with a good deal of Water, this

Earth ſoon becomes fertile, and bears a thouſand different Plants[a]. The Heat diſengages the Seed from the terreſtrial Particles, opens its Pores, and diſpoſes it to receive the nutritive Juices. *Virgil* was equally a Poet and Philoſopher, when he ſaid,

Sæpe etiam ſteriles incendere profuit agros,
Atque levem ſtipulam crepitantibus urere flammis;
Sive inde occultas vires, & pabula terræ
Pinguia concipiunt; ſive illis omne per ignem
Excoquitur vitium, atque exudat inutilis humor;
Seu plures calor ille vias, & plura relaxat
Spiramenta, novas veniat quà ſuccus in herbas, &c.

2. [b] Steep in Aqua-vitæ ſome Seeds, Lettice, Colliflower, Sallet, *&c.* Mix with Mould ſome ſlaked Lime reduced into Powder, with a little Pigeon's Dung; in twice 24 Hours you will have Lettice, Colliflowers, Sallet, *&c.*

3. [c] Would you have Parſley? Soak ſome Parſley-Seed in Vinegar, and after having ſown it in good Earth, throw upon it plenty of the Aſhes of Bean-cods; after that beſprinkle the Earth with Spirit of Wine, and cover

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[a] Hon. Fabri. l. 2. de Plantis, Prop. 99. p. 58.
[b] Journ. des Sçav. 9 Sept. 1675. p. 239.
[c] J. des Sçav. 1666.

it well with Linnen-cloths. The Parſley will ſpring up out of the Earth in few hours.

4. If you deſign to raiſe Peaſe and Beans quickly, nothing more is required than to put them into hot Oil for the ſpace of nine Days, and then to grind and ſow them. The Beans and Peaſe will ſpring up in an Hour [d].

Ariſt. They compare the Roots to the Stomach of Animals.

Eudox. Becauſe the Roots, like the Stomach, receive the Nouriſhment, digeſt, alter and change it into nutritive Juice. Accordingly whenever the Nouriſhment has paſt from the Roots into the Stalk, one may obſerve, that it has taken a particular Odour, Colour and Taſte [e]. The Action of the Air meliorates the Juices in the Trunk. The Heat of the Sun refines them there, by the Agitation and Diviſion of their Particles. Perhaps you will not believe what ſeveral Authors have advanc'd, that Plants are formed in the Body of Man. Nevertheleſs the *German* [f] *Ephemerides* ſay, that a Man voided ſmall Muſhrooms from time to time, as others do Stones, and that they found, near the right Kidney of a Man 55 Years old [g], a Cluſter of ſmall Muſhrooms. A *Dutch*-man ſpeaks of a Muſhroom formed in the Bladder as big as an Hen's Egg. A Cane of Sugar, which an Author tells us had taken root and ſent forth Leaves in the Stomach of an Elephant, is a thing too ſurprizing to appear credible. May not one ſwallow Seed, which may find in the Chyle or nutritive Juices, particular Juices capable of opening it?

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[d] Journ. des Sçav. 7 Fev. 1684. p. 47.

[e] Mem. de l'Acad. 1707. p. 281.

[f] Journ. des Sçav. 9 Fev. 1679. p. 35.

[g] Journ. des Sçav. 13 Fev. 1679. p. 48.

Would you believe, *Ariſtus*, that in *Canada* they have extracted a Species of Sugar from the Maple-tree[h]?

Ariſt. There are Seaſons wherein the Veſſels of Trees are full of Juices; as the Spring and Summer. This exceſs of Juice is the Sap. The Spring is the Seaſon of the firſt Sap; and Summer is the time of the ſecond. In the time of the Sap ſeveral Trees throw out their Sap abundantly, if their Bark be but a little wounded. The exceſs of Juices ouzes out and diſtils thro' the vent by the Motion of its Elaſticity and Liquidity. Hence the Balms and Turpentine, which proceed from Pine-trees. Now if we ſee Trees ſo full of different Juices, why may not ſome be found which bear a Juice of which they may make a Species of Sugar?

In the time of the Sap the Trunk is eaſily ſtript of its Bark.

Eudox. Becauſe the Juice, which flows in abundance betwixt the Bark and the Wood, detaches the Bark from it by its Motion and Elaſticity.

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[h] Mem. de l'Acad. 1707. p. 277.

The chief Production of Branches happens at the top of the Trunk, and when the Tree is lopped, one ſcarcely ſees any new Buds but where it was lopped.

Ariſt. Becauſe probably the Sap being thrown directly from below upward, is not ſufficiently ſtopt till it be at a certain height from the Earth, neither does it receive an oblique Direction ſtrong enough to turn it aſide, and force the Buds that are towards the outpart to ſhoot out and open.

The hardeſt and oldeſt Trees ordinarily ſhoot out their Leaves later than the others.

Eudox. Becauſe their parts being more cloſe and compact, the Sap finds in them paſſages leſs free; and the budding is later in them than in Trees whoſe parts are more flexible, and more impregnated with Juices.

What think you, *Ariſtus*, of what we are told of an Aloes, which after having been in the Garden of *Montpelier* time out of mind, ſuddenly ſhot out a Stem when it ſeemed to be withering and dying, ſo prodigious that in leſs than 24 Hours the Stem aroſe to the height of 20 foot, with a noiſe of Thunder[i]?

Ariſt. Perhaps the hardneſs of the Bark or Covering had for a long time retarded the riſe of the Stem, it might have been folded, the Juices being impregnated with Air, had penetrated into the Fibres with violence; a great quantity of other Juices had remained about the Roots, and finally the ſudden Rupture of the Bark or Covering, had at once afforded a free Paſſage.

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[i] Mem. de Trev. Nov. 1708.

The Stem being ſhot out by ſome violent Fermentation, and by the Spring of the internal Air extraordinarily compreſs'd, muſt have been too quickly explicated with its Leaves. The Juices heaped up round the Roots had entered rapidly into the Plant by the exceſs of Fermentation. The Fermentation and this abundance of Juices produced this ſudden Accretion. And the ſuddenneſs of the Explications would cauſe in the Air that impetuous and alternate Motion which made the Noiſe.

Eudox. However that be, Honey or a Species of Manna is found upon the Leaves of certain Trees. They have often remarked upon Leaves, and particularly upon Leaves expoſed to the Sun, a viſcous, oily and ſweet Moiſture, of which no traces were to be ſeen upon the Plants till after the Sunriſing *.

They have ſeveral times obſerved the Bees gather this Matter upon the Leaves of Trees, and load themſelves with it as they load themſelves with a Juice of the ſame nature, which is found upon the internal Surface of the bottom of Flowers. Now this Juice is a Species of Manna or Honey. Accordingly Honey, as *Pliny* has remarked, retains the Taſte of the Plants from which the Bees have gathered the Juices. Hence in certain places it is pernicious, in others moderate, and in ſome exquiſite. But whence proceeds this Species of Honey or Manna? Is it from the Dew, as the Antients believed?

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* Mem. de l'Acad. 1707. p. 277.

Ariſt. It is the moſt exalted and elaborate part of the nutritive Juice of Plants. This part of the Juice being refined and rarefied by the Heat, is thruſt into the Fibres of the Leaves; and forced to come out, it tranſpires thro' the leſs contracted Pores. Is it not true that the Manna of *Calabria* is the extravaſated Juice of the Aſh-tree[k]? Hence Honey retains the Taſte of Plants upon which it was gathered.

Do you believe, *Eudoxus*, that Leaves are very neceſſary or uſeful to the Fruit?

Eudox. The Juices are brought to perfection by circulating in the Leaves; they are thereby the more delicate. Beſides, Leaves ſerve to defend the tender Fruit from the injuries of the Air. Accordingly when the Caterpillars devour and conſume all the Leaves, you ſee the Trees languiſh and bear only abortive Fruit.

Ariſt. But why are the Trees, which are too fertile, the leaſt durable?

Eudox. Becauſe in proportion to their bigneſs they expend too much Juice in nouriſhing their Fruit, and do not reſerve enough of it for nouriſhing the Roots, Trunk, and Branches, as we have already obſerved. Accordingly, they not only cut Vines in order to make them ſhoot out more Branches, but alſo that they may not bear too much Fruit, as Hedges of low Vines do, which have never been cut. They bear a great quantity of Fruit. For which cauſe the Vine-dreſſers, who dreſs Vines which they farm, ſometimes neglect to cut them the laſt years of their Leaſes, or cut them too long, that ſo they may have the more Fruit, and this is what they call *drawing to the Wine*[1] *. But if they neglect to cut the Hedges for two or three Years, they decay thro' the continual bearing and conſuming their nutritive Juices.

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[k] Mem. de l'Acad. 1707. p. 278.

Oftentimes when they cut the great Branches of Trees, they cover the Wound.

Ariſt. That is to hinder the Juice from running out, and to oblige it to diffuſe itſelf into the Subſtance of the Trunk or other Branches. They likewiſe make a ſort of Dreſſing for the Wounds of Trees which they have grafted, in order to reunite the Juice, and to conſtrain it to run thro' the Scyon, and by its thickening, to make a kind of Cicatrice, whoſe Edges ſwelling, recover the Wound.

Graffed Olive-trees from which you cut off the Bark below the Graff, without cutting the ſuperiour Branches, bear more Fruit that Year.

Eudox. Probably becauſe the Juice, which makes the Flowers and Fruit, is that particularly which paſſes through the Pith, as we have obſerved; and becauſe the Bark being cut, the Juice which that ought to convey, is filtred and mixed with that of the Pith.

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[1] Mem. de l'Acad. 1707. p. 284.

* *Tirer au Vin.*

Have you obſerved, *Ariſtus,* that Orange and Fig-trees being planted, in ſmall Boxes, bear the more Fruit [m]?

Ariſt. Becauſe in the ſmall Boxes the Sap of the Orange and Fig-trees not finding room to extend itſelf in the contracted Roots, is employed in greater abundance in making the Flowers and Embryo's of the Fruit to bud.

Why do they make the Beaſts eat that Corn which bears too many Leaves?

Eudox. In order to force the nutritive Juice to filter into the Stalk, and to make it run up into Straw. Bnt laſtly, what cauſes the Maturity of Fruit?

Ariſt. The Heat divides and attenuates to a certain degree whatever is too aqueous in Fruits, and renders the imperceptible Particles finer and more proper for ſtriking the Taſte without hurting it; and this is maturity.

But do you believe, *Eudoxus,* that there is in Plants an imperceptible Tranſpiration?

Eudox. Why do we ſee Plants incline toward the Earth, and flag in the Heat, and reſume their former vigour when the Cool returns? Becauſe the Heat throwing out of the Plants, by an imperceptible Tranſpiration, a great quantity of Corpuſcles, the Fibres are emptied, relaxed, loſe their firmneſs, and yield to the force of Gravity for want of Corpuſcles or Spirits capable of ſwelling the fibrous Tubes. Therefore when the Bodies of Animals have ſweated very much, they grow faint, becauſe an exceſſive Tranſpiration has deprived them of the Spirits neceſſary to animate the Body. But ſhould the Cool give new Juices and new Spirits to Plants, they ſwell the Tubes, fill and ſtraiten them again; and this is to reſtore Plants to their former vigour. Thus when fatigu'd Animals are refreſh'd, new Spirits fill the Nerves, and reſtore to them their former vigour and firmneſs.

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[m] Mem. de l'Acad. 1705. p. 335.

The Motion of the Turnſole, which ſeems to follow the Sun, does it not proceed from an exceſſive Tranſpiration?

Ariſt. The parts of this Flower turned toward the Sun, being relaxed by the exceſſive Tranſpiration of their Juices, while the parts turned away from the Sun are not at all ſo, or at leaſt much leſs, find themſelves conſtrained to ſink under the weight of the Leaves and Flowers, and to ſuffer them to incline toward the part which affords them the weakeſt Prop. This part is toward the Sun. Hence the Turnſole ſeems to follow the Sun, or to turn about at the pleaſure of this Planet.

Eudox. It is likewiſe probably the action of the Sun which makes ſome ſort of Roſes in *China* appear to change colour twice a day, and to be ſometimes white, and ſometimes of a fine red mixt with a little Violet like the Purple.

ple. The texture of the Fibres being changed by the action of this Planet, by the difference which it cauſes in the Juices, remits the Rays differently, and the Rays being differently modified and matched; make thoſe different colours, which the ſame Flower alternately preſents to the Eyes.

Ariſt. But why does the Convolvulus ſhut up in the night-time, while the Marvel of *Peru* is blown?

Eudox. That proceeds from the different extenſibility of Plants. If Nightſhade has Pipes hollow, flexible, and as it were outwardly cylindric, they will ſwell in the Night, become ſtrait, open the Flowers, and blow. The Sun will dry up thoſe Tubes in the Morning, the oppoſite ſides of the Flowers will be drawn back by the action of their Spring, and the Flowers will hide themſelves in the day-time. By a contrary Diſpoſition of the Tubes, the Convolvulus will ſhut up in the Night, and open in the Day.

A young Plant ſhut up in a Cellar, or in a Room, whoſe Window is open, turns as of itſelf towards the Air-hole or Window.

Ariſt, The young Plant being impell'd by the Juices, which circulate in its Subſtance, and by the Air which ſurrounds it, and being very flexible, ought to turn its Stalk and Branches toward that ſide where the Preſſure is leaſt. Now the Preſſure of the Air is leaſt toward the Vent and Window; for there the

Air yields oftner and more eaſily, becauſe it has there a neighbouring Paſſage, and is more rarefied and warmer. By the ſame principle Trunks and Branches ſeem to avoid Eſpaliers.

But whence can the twiſting of the Hops and other Plants of this ſort proceed?

Eudox. Theſe Plants being too feeble to ſupport themſelves, and meeting with a Body proper to ſuſtain them, lean upon it; the tender Fibres which touch the Body that ſerves them for a Prop, being contracted by the Compreſſion, ſhrink a little, while the external and oppoſite Fibres are lengthened. This contraction of the Fibres determines the parts, which grow up afterwards, to ſtay themſelves after the ſame manner. Their Fibres are alike contracted, and produce the ſame Effect. Hence the twiſting of Plants.

I don't know whether you have ſeen Branches of Trees preſs'd down by the weight of Oiſters. Father *du Tertre*, a Jacobine, in his Hiſtory of the *Antilles* [n], ſays, that he ſaw in the Iſland of *Guadeloupe*, ſeveral Trees ſo loaded with Oiſters, that the Branches of them broke, being bent down under the Weight: and the ſame hath been obſerved near *Plymouth* [o].

Ariſt. Probably the Waves of the Sea, which are ſpread over thoſe Branches, depoſite on them the Seed of Oiſters, which is attach'd to them; and the Oiſters being hatch'd, are nouriſhed there ſo much the more eaſily, becauſe the Flux and Reflux of the Sea refreſhes them twice a day.

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[n] Journ. des Sçav. 25 Avril, 1667. p. 88. Hiſt. des Antilles.

[o] Hiſt. of Nat. Rarities of *England*, Journ. des Sçav. 1667. 13 Juin, p. 115.

Eudox. Plants are often a Prey to Inſects; but their being impregnated with certain Salts is ſufficient to protect them, becauſe thoſe Salts are hurtful to Inſects, whoſe Fibres they tear into pieces. For example[p], they boil in a Pail of Water, for the ſpace of half an hour, Rue, Wormwood, and *Virginia* Tobacco, an handful of each; after that, they preſs out the Water, and with it they water Plants three or four times when they are in Bloſſom: this is enough to ſecure them from Caterpillars and black Flies; and an inlaid Floor being ſoak'd with water, with which one has mix'd corroſive Sublimate, is inacceſſible to certain Worms, which otherwiſe would eat into it[q].

One thing ſtill, which at firſt may ſeem ſurprizing, is, that in the *Antilles* every thing ſhoots forth during the Winter[r].

The Fields there are then covered with green. On the contrary, in Summer, the Leaves fall off, and the greateſt part of the Plants die. One ſees the Reaſon of it very ſoon. In thoſe Iſlands it is hot even in the Winter itſelf, and in Summer the Plants are burnt up with exceſſive heat.

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[p] Journ. des Sçav. 3 Juin. 1675. p. 156.

[q] Hiſt. de l'Acad. 1705. p. 38.

[r] Hiſt. des Antilles. Journ. des Sçav, 1667. p. 88.

Would you believe, *Ariſtus*, that Plants die at laſt for want of Reſpiration? The Reſpiration of Plants is one of the Obſervations of M. *Malpighy*, confirmed by a later Author in a very ingenious Diſcourſe upon this Subject [f].

Ariſt. I only waited, *Eudoxus*, for your Opinion upon the Reſpiration of Plants.

Eud. 1. When we ſee Fiſh die for want of Air in purified Water, we reaſonably judge that they reſpire in Water itſelf. Now Plants die as Fiſh do, in purified Water; and Water impregnated with Air preſerves their life. Therefore one may ſay, at leaſt with ſome probability, that Plants reſpire.

2. We are convinc'd that Inſects have need of Reſpiration in order to live, becauſe Oil which ſtops the Ducts of their Reſpiration, makes them die. Now the mere ſmell of Oil is ſufficient to make ſeveral Plants die; a drop of Oil being put to their Roots is ſufficient to kill a great number of them. Therefore it is probable that Plants have need of Reſpiration as well as Inſects.

3. In ſhort, if Plants attract the Air, and reject it ſucceſſively, this is a ſort of Reſpiration: But, 1. Plants attract the Air; for it is certain that thoſe green Branches, which while they burn on one ſide, ſend forth on the other a Puff like to that of the Æolipile, contain very much Air. Fruit whoſe Subſtance is ſpongy,

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[f] Mem. de Trev. 1712. Mai.

as Citrons and Oranges, are hardly any thing elſe than a number of ſmall Corners full of Air. Green Peas and Beans newly gathered, are inflated even to burſting by the dilatation of the internal Air in an Air-Pump. 2. Plants throw out Air. As they tranſpire conſiderably, and inceſſantly receive new Particles of Air with their Nouriſhment, if they always retain'd the ſame Air, the Air ought to ſwell them ſtrangely, break their Fibres, and make them fade away.

4. Laſtly, to receive and reject the Air alternately is Reſpiration. But Plants receive and reject the Air alternately. They cannot dilate and contract themſelves alternately, without receiving and rejecting the Air at the ſame time; and they do dilate and contract themſelves after that manner. The Juices propelled by Fermentation into the Plants ought to dilate the Tubes, and the Elaſticity ought afterward to contract them. Therefore, *&c.*

Accordingly in the internal part of the Roots they perceive two ſorts of Ducts, the one which receives the Juice, and theſe are the ligneous Tubes; the other, which carry the Air into the Cellules, are the Tracheæ. Theſe Tracheæ very much reſemble thoſe of Inſects, and are diſpers'd after the ſame faſhion; being diſpoſed along the Plant, formed of a minute Lamina, ſometimes united in their courſe, and ſometimes widened in form of ſmall Cells. Theſe Cellules are probably Reſervoirs and

Lobes, if I may ſo call them, into which th Air is conveyed through the Tube of the Trachea, in order to paſs thence into the Juices, and to give them that fluidity which is requiſite for their Circulation, and conveying Life to the whole Plant. This Air, which entered in the Dilatation, iſſues out at laſt in the contracting of the Plant. Hence in ſome ſmall Pores of ſeveral Sponges, which come from the Sea, there is obſerved a kind of Motion of Diaſtole and Syſtole[t].

Ariſt. I believe, *Eudoxus*, that ſo great a number of Effects being explained, may furniſh us with the Knowledge of an infinity of others.

Eudox. The Knowledge of the human Body, and of Plants, affords us a general idea of the Structure and Mechaniſm of the Bodies of Animals. Nevertheleſs, Animals deſerve at leaſt one Converſation.

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[t] Hiſt. de l'Acad. 1710. p. 73.

CONVERSATION VI.

Upon Animals.

Eud. THE generality of Mankind make no great account of Animals; they tread Inſects under their feet: yet whenever we look upon the ſmalleſt Inſects, or vileſt Animals, as Philoſophers, the Mind is ſeized with admiration. What variety of Species! We quickly ſee that the bountiful hand, which formed them, muſt have been guided by an infinite Wiſdom.

Ariſt. Probably all Animals proceed alſo, as well as Men, from Sperm or Eggs, which the Author of Nature placed at firſt in the firſt Animals of every Species, and which want only to be hatched and unfolded.

Eudox. You give them a noble Origine. Some great Philoſophers have vilified the original of Inſects ſo far, as to attribute it to Corruption. Corruption hatches them; but this is after the Flies have depoſited their Eggs. Thus ſuch Bodies as ſeem to engender ſmall Inſects, when they are corrupted in a part acceſſible to the Flies, produce none when they happen to be corrupted in a part to which the Flies have no acceſs *. Could Chance, a fortuitous Concourſe of Particles, produce Beings ſo regular, and in which Art is ſo much ſuperiour to the underſtanding and skill of Men?

The Eggs being once formed, we conceive how the Embryo is explicated. How is it hatched, for example, in an Hen's Egg? A certain degree of Heat agitates the liquid Matter, which encloſes the Embryo; the Heat divides this Matter, attenuates, digeſts, and makes it flow through the Navel into the Body of the little Animal. The Veſſels which receive it ſucceſſively, direct it toward different parts of the Body, in order to convey to them Nouriſhment, Accretion and Life. Do you know, *Ariſtus*, in what manner they hatch Eggs in *Ægypt*, without the Aid of the Hen?

Ariſt. I ſhall be glad to learn it.

Eudox. It is equally curious and certain. I learned it from a Perſon who ſaw it †. There are Ovens for Chickens. Theſe Ovens are in hollow places and built in form of a Dortoir, with an Alley in the middle, and four or five Rooms on each ſide. The Door of the Alley is low, narrow, and ſtopt with Tow, in order to preſerve the Heat. The Rooms are four or five foot in breadth, and fifteen in length, or thereabouts; they have two Stories, the one level with the ground, the other has two floors. The lower one has a round hole in the middle, and the other is vaulted like a Dome, but open. Inſtead of a door, every Story has a little window, a foot and half round.

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* Le Clerc. des Animaux, c. 3. Redi. des Inſectes, p. 135.

† Mem. des Miſſions de la Comp. de J. dans le Levant, p. 79. Tom. 7.

At firſt they put four or five thouſand Eggs at leaſt into the lower Story. They kindle a Fire in the upper Story, for an hour in the Morning and another in the Evening, during the ſpace of eight days. This Fire is made of Cow's Dung, or the Dung of other Animals, dried and mixt with Chaff. While the ſmoak comes out of the hole in the upper ſtory, they cloſe up with Tow the round hole of the Dome, and the little window of the lower ſtory, that ſo the heat may be communicated thro' the vent of the floor to the ſtory where the Eggs are.

After the eighth day, they ſuppreſs the Fire. They put a part of the Eggs into the upper ſtory; where the Fire was dayly kindled. They ſhut up the ſmall Windows of the two Stories. They half open the upper hole of the Dome to let in Air. The Eggs are thirteen days in this condition of an agreeable and concentric heat, which prepares, inſenſibly digeſts the nutritive Juice, and makes it flow into the ſubſtance of the Embryo. The eighteenth day after operation, "you may ſee "thro' the Shell the Embryo ſtir and nouriſh

" it ſelf with the Yolk, which it ſucks in " thro' the Navel. The twentieth the young " Chick ſplits the Shell with its Beak." He that manages the Oven, widens the gap a little with his nail. The one and twentieth at noon, or the two and twentieth in the morning, the Shells are broke, and the Chickens are freed from their Priſons. There is at once an Army of little Volatiles. Yeſterday you might have ſeen thouſands of inanimate Shells, and to-day they are thouſands of ſmall living Birds, which have no ſooner ſeen the light than they know how to diſcern and lay hold on what may preſerve their life.

The wonderful Operation of Chicken-Ovens can only be performed during the Autumn and Winter. The Spring and Summer are too hot.

Ariſt. I admire the Art which hatches thouſands of Chickens at the ſame time. Would it not ſucceed in *France?*

Eudox. The Directors of the Chicken-Ovens have offered themſelves to come and build ſome here, anſwering for the ſucceſs.

However it be, the idea which we have of our own Body may be of uſe to us in penetrating into the Mechaniſm of the Bodies of Animals. But let us not attempt to unravel all that is curious and ſingular in every Species. Life would be too ſhort. Let us however recollect ſome traces of the Hiſtory of Animals.

For my part, I am charmed when I read the Obſervations of *Ariſtotle* upon Bees[a], or when I obſerve in a Bee-hive of Glaſs, or in a Flower-garden, the Structure of Bees, their Number, Government, Functions, Induſtry and Paſſions. Bees[b] have two Jaws or Jaw-bones in the Head, and a Trunk near the Neck; ſix Feet; a ſmall Bladder deſtin'd to receive and bear the Honey, which they ſuck with the Trunk, and reject thro' that part of the Head which is between the two Jaws; and a Sting in their hinder part. They make uſe of their Sting not ſo much for attacking others, as defending themſelves. It terminates inwardly in a little Bladder full of a venomous Liquor, and is hollow. When the provok'd Bee ſtings any one, the Liquor being compreſſed, iſſues out thro' the paſſage near the point, flows into the Wound, and inflames it. Nevertheleſs, if you draw it out quickly, little venom enters, and there happens but a ſmall tumour. If the Sting, being ſtruck in, is grappled in the pricking, it remains there, the Body of the Bee is torn in the effort which it makes to fly away after it has avenged itſelf; and the Wound which it has made in you, coſts it its Life: *Animaſque in vulnere ponunt*[c].

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[a] Book 9. of the Hiſt. of Animals, c. 40. Book 3. of the kinds of Animals, c. 10.

[b] Mem. de l'Acad. 1712. p. 299.

[c] Virg. Georg. lib. 4. v. 238.

Oftentimes there are 8 or 10 thouſand Bees in one Hive; they have counted as good as 18000. They find among them a conſiderable number of Drones, which are ordinarily one third bigger and longer than the Bees, and without a Sting. Sometimes one ſees in a Swarm two or three Bees at moſt which are longer, and of a more lively colour than the Drones, but not ſo large in proportion to their length. Commonly there is only one of them, which is eaſily diſtinguiſh'd from the Drones by its Colour, Bulk and Shape; and this is the King. This King is doubly the Father of his People, ſince he knows how to make Plenty and Order reign in his Dominions, and becauſe he alone has Fruitfulneſs to his ſhare. Amongſt the People of the Bees ſome are deſtin'd to go and gather Wax and Honey upon Leaves and Flowers; others to take in the Crop, and to raiſe the Edifice of the Combs; others to poliſh and perfect them; and ſome to hinder the indiſcreet and raſh Inſects from coming to diſturb the publick order and repoſe.

The Wax which is gathered upon Flowers, ſeems to be the Duſt of the Stamina. The Bees which gather the Wax, make it paſs into a Cavity which they have in their Hind-Legs. Sometimes in order to carry off ſmall Particles of Wax with all the Hairs, wherewith their Body is covered, and to load themſelves on all ſides, they roll themſelves upon the

Flowers. When they arrive at the Hive, they make themſelves heard by a motion of their Wings; and others often come and aſſiſt them to unload, take the Wax, temper it, knead it, and go to work with it.

For the moſt part they begin the Edifice at the top of the Hive. It conſiſts of Combs. The Combs are Planes perpendicular to the Baſe of the Hive, and perforated with a number of Holes. The Holes are Hexagons, or ſmall Cells with ſix ſides, every one of them fit for the containing a Bee. In proportion as thoſe which build the Walls of the ſmall waxen City advance their work, others are employed in perfecting and poliſhing it with their Jaws; they turn the Angles after a curious manner, plain the Surfaces, finiſh the Sides and Baſes, and compleat the Whole.

Oeconomy ſtores up the ſuperfluous Particles of Wax in ſome Cells, while Fore-caſt goes in queſt of Honey. The Bees, which are charged with the care of gathering it in, conſume only a ſmall portion of it for their own nouriſhment, carry off the reſt in their little Bladder, and depoſite it in the Cells, which are as it were the publick Magazines, where the People find ſweet nouriſhment in Winter, when they have a mind.

The Bee-holes for the moſt part are the Cradles of the young ones.

Ariſt. But how are the young ones brought forth? How are they reared?

Eudox. The King, or rather the Queen of the Bees, (for ſhe is the Mother of the Bees) being attended with ten or twelve Bees that are moſt conſiderable, and walking with a grave and ſedate pace, viſits the Bee-holes. She hath been obſerved [d] to enter into eight or ten Cells, one after another, and to leave in every one of them a little white Worm, or an Egg. While the great Bee is in a Cell, thoſe who attend her are diſpoſed in the form of a Circle; and if you ſaw the Action, Air, and Motions of the Retinue, you would ſay that they were forward to careſs her with Feet and Trunk, and applaud her on account of her Fertility. The teeming Bee places in the largeſt Holes the Eggs which ought to produce the Drones, and the Kings or Queens. After four days the heat of the Hive makes the Eggs to hatch ſmall Worms. Sometimes the Bees ſprinkle a certain Liquor over theſe little Worms. The Worms are explicated, and they bring them Honey for nouriſhment. After eight days they ſtop up the Holes with ſmall coverings of Wax, very thin. About twenty days after the Eggs have been laid, you ſee young Bees bore thro' the door of their Cells with their Jaws, make themſelves paſſages, fly away the ſame day, being probably allured by the ſcent of the Honey and Wax, gather the Wax and Honey upon the Flowers, and with dexterity depoſite their

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[d] Mem. de l'Acad. 1712. p. 313. M. Maraldi.

Harveſt in the Magazines of the Hive. Scarcely are they brought forth, but they know all the cuſtoms, and all the uſages of the Manſion which has ſeen their Nativity. Already are they as zealous for the publick good, and as skilful, as thoſe which have grown old in the exerciſe of all the Employments, thro' which one may paſs in the Empire of the Bees.

But would two Swarms live there any long time together? One muſt give place. It is ſcarcely departed, when that which remains ſets itſelf to produce a new one. They labour night and day in the Hive, in Summer, peaceably enough. But Peace cannot laſt long amongſt Men, why ſhould it reign always amongſt Animals? From time to time there are ſingle Combats amongſt the Bees; and toward the end of Summer, when the crop of Honey is not ſufficient for Winter, there is ſometimes a general battle. The ſight of the Drones, which they conjecture to be the Males, but which then become uſeleſs, provokes the people of the Bees, and the indignation of this people, however wiſe, becomes terrible. They are ſeen to throw themſelves in crowds upon the Drones, and to drive away or kill them. There is no quarter; their victorious fury does not ſpare the young Drones themſelves. They pull them away, even thoſe little ones, from their holes, that they may cut them to pieces; they tear them unmercifully; and in a ſhort time you ſee the bottom of the Hive covered with their ſcattered members.

But Bees have a dreadful enemy in the cold. In order to ſecure themſelves from it in Winter, they agitate themſelves; and this agitation cauſes a heat, which is communicated to the glaſſes of the Hive, where it is very perceptible.

Theſe Obſervations are curious; they affect me; I know not whether they make the ſame impreſſion upon you.

Ariſt. Can one obſerve, without amazement, in theſe ſmall Inſects, ſo much Foreſight, Induſtry, Love of order, and pacific and warlike Inclinations? My imagination recollects a ſpecies of Animal, which diſcovers much leſs underſtanding, but is infinitely bigger; and that is the Whale. I love to fancy to my ſelf a Whale of 60 [e], 100, 200 foot long: Natural Hiſtory aſſures us that ſome of them have been ſeen of this bigneſs [f], and they ſay that the Head makes up a third part of their Body [g].

Eudox. If theſe huge Animals were as furious as the provok'd Bee, with a blow of their Tails they would make Shallops fly in pieces, and would be terrible to Ships.

Ariſt. Luckily the Whale does not make uſe of its ſtrength to do any miſchief. It wiſhes no evil; not even to thoſe who think on nothing elſe but to deſtroy it. It flies continually, and this is what emboldens Avarice to purſue it. One Whale alone, of about 60 foot in length, yields an hundred Hogſheads of Oil. Thus the North Sea is ſometimes covered with between ſeven and eight hundred Shallops, employed in fiſhing for Whales. There are in one Shallop ſix or ſeven Men. One of them, who is upon the fore-part, holds in his hand a Harping-Iron, which is at the end of a Rope of ſome hundreds of Fathoms. The Harpineer darts the Whale. The Whale being wounded, contracts, and being contracted, becomes heavier than an equal volume of Water; being heavier, it ſinks and runs away with rapidity. The Rope runs, the Rowers who hold it, follow. The Strength of the Whale is at laſt exhauſted by the loſs of Blood. When they perceive it to draw weakly, ſeveral Shallops unite together to draw it back, and they put an end to its life by darting it with Spears[h].

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[e] Mem. de Trev. 1717. p. 2003.
[f] Journ. des Sçav. 1683. p. 351.
[g] Mem. de Trev. 1717. p. 2003.

Eudox. You ſeem, *Ariſtus*, to have reſerved your admiration for the biggeſt Animals; and yet the ſmalleſt are thoſe which ſurprize me moſt. Is it not aſtoniſhing that the ſurface of the Earth is overſpread with an innumerable multitude of Animals almoſt infinitely ſmall, who find their nouriſhment both in the Juice of Plants, and alſo in

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[h] Mem. de Trev. 1717. p. 2004.

Minerals? The greateſt part of Minerals and Plants being infuſed in Water, make it ſwarm with Inſects inviſible to the naked Eye. I have ſeen thouſands of them with a Microſcope in the hundredth part of a Drop. They ſwimmed in it, met one another without claſhing, and leapt about at freedom, now toward one ſide, then toward another. Theſe living Atoms muſt have in their inexpreſſible ſmallneſs, Feet, Bowels, Heart, Eyes; Organs for Nutrition, Motion, and Generation; Blood, Arteries, Veins, Nerves, and Muſcles; and the various members of every Inſect, tho' infinitely ſmall, are to that Inſect as thoſe of a Whale are to the Whale. If it requires a Wiſdom ſo far above human Underſtanding to give Organs to the Whale, what Wiſdom is there not neceſſary to organize Bodies ſo infinitely ſmall?

Ariſt. An Animal more ſingular than either the Whale or your infinitely ſmall Inſects, is the wild Man of the Iſland of *Borneo*. It is difficult to imagine to one's ſelf a Monſter which under the human ſhape is only a Beaſt; nevertheleſs here is the extract of a Letter written from the *Indies* the 10*th* of *January* 1700[i]. " The 19*th* of *May* 1699, being at the Road " of *Batavia*, I my ſelf ſaw upon the *London*, " an *Engliſh* Frigate coming from *Borneo*, " one of thoſe Savage Men, who was only " as then three Months old, about two foot

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[i] Mem. de Trev. 1701. p. 184.

“ high, cover'd with Hair, but ſtill very ſhort. He had a round Head, and very like to that of a Man; Eyes, Mouth and Chin, a little different in Shape from ours. I dare not give him a Noſe. When he lies down, it is upon his Side, upon one Hand. I found the Pulſe in his Arm ſuch as we have. The Stature of thoſe Animals at full growth equals that of the biggeſt Men. Mr. *John Flower*, Captain of the Veſſel, told us that he had killed one with three Balls. They run ſwifter than Deer. They break down the Boughs of Trees in the Woods, which they make uſe of to knock down Paſſengers. When they can kill any one, they ſuck his Blood, which they reliſh as the moſt delicious Drink. When I went to *Malacca*, there were three of theſe wild Men of *Borneo*.”

If there are Sea-Men, the Man of *Borneo* is not an incredible thing. But M. *Clouer* ſays, that he had ſeen in a River of *Virginia*, a marine Monſter which appeared with the Tail of a Fiſh, but having the Head, Arms, Air and Viſage of an *Indian* [k]. They affirm, that in 1671, ſix Perſons ſaw another near *Martinico*, which had the Eyes ſomewhat large, the Noſe flat, the Face full, Hair lank and ſmooth, mix'd with white and black, and flowing upon the top of his Shoulders, with a grey Beard, which hung over his Breaſt; the lower part terminated in a Tail, large and forked. A Certificate made before the Notaries of the Country atteſts the fact.

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[k] Journ. des Sçav. 1676. p. 351. Copied out of an *Engliſh* Journal.

Eudox. The Idea of theſe ſorts of Monſters brings to my mind another Species which is mentioned in the Hiſtory of the Knights of *Malta*[1]. It was a terrible Serpent, covered with Scales, except under the Belly. This horrible Beaſt laid waſte a Country of the Iſland of *Rhodes*. The Knight of *Gozon* cauſed an Image to be made of it, in wood or paſteboard, very much reſembling it. He trained up two young Maſtiffs, and accuſtom'd them not only to ſee this Figure, but to leap at it, and ſeize it under the Belly. When he ſaw his Dogs train'd up for this kind of fight, he had the boldneſs to attack the Monſter itſelf with his warlike Maſtiffs. The Knight was confounded at firſt; but his Maſtiffs ſeeing nothing that was new to them, threw themſelves without dread upon the Belly of this terrible Animal; they faſtned themſelves to that part which was acceſſible, and tore it to pieces without letting go their hold: and the Knight, after having expected to periſh in the conflict, at length obtained his end with the aſſiſtance of his Dogs, deſtroyed the Monſter, and freed the Country from it.

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[1] Hiſt. des Cheval. de Malte, Tom. 2. 3 Edit. p. 194. par M. de Vertot.

Ariſt. You may ſee in a Letter written from the *Indies*, a ſhort time ago, by a Miſſionary [m], a Stratagem ſomething like this, which had the ſame Succeſs. An enormous Monſter *, a Serpent of a prodigious ſize, whoſe length was about eight or ten foot, had his retirement in a Mountain near a River. When he eſpied a Shallop, he went under water to ovrturn it, and at his leiſure devoured thoſe who were on board. A Criminal, who had his life promiſed him, thought of faſtning a Rope to a Tree by one end, and Men of Straw with the other, which appear'd upon the ſurface of the water. Theſe floating Men were filled and briſtled with Hooks, Tenters, and Grapples. The Monſter being allured by Figures like thoſe with which he had often fed himſelf, failed not to ſeize them greedily, and faſten himſelf with the Grapples. In vain did he attempt to diſintangle himſelf, he only hooked himſelf the faſter. This deſtructive Animal was torn to pieces by the Tenters and Grapples which he ſwallowed down, and the Country was delivered from a Monſter fatted with human gore.

Eudox. I ſaw this morning [n] a Monſter leſs dreadful, but a true Monſter. It is a Roebuck, ſeemingly three or four months old at leaſt, with two Heads upon one Neck. The two Heads are well ſhaped, and almoſt of equal bigneſs. Each Head has two Eyes and a Mouth. The Animal ſeems equally to have made uſe both of the four Eyes and the two Mouths. The two Heads, after having made a pretty large angle, are united upon the extremity of the Neck. They have three Ears, one double and two ſingle. That which is in the part where the Heads join, has two paſſages, and makes a triangle with the others. Probably two Eggs or two Embryo's have been laid cloſe to one another, and the juices by making a free paſſage to circulate from the one into the other, at leaſt from the one into the head of the other, have inſenſibly fortified their Union, and formed this monſtrous Animal in the Foreſt of *Compiegne*. The King lately caught it there in hunting. Could the Monſter periſh more honourably? Poets can make the fineſt and moſt lucky Alluſions and Predictions. May not Philoſophy itſelf, which pretends to ſay nothing but truth, make ſome without any hazard?

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[m] 18 Recueil de Lettres édifiantes & curieuſes de quelques Miſſionaires, p. 49.

* As to the ſeveral Monſters here mentioned, little regard is to be had to the Accounts of them, they being generally delivered to us by Miſſionaries, who are for the moſt part very romantick.

[n] 13 *May*, 1729.

Ariſt. This real and rare event renders probable, at leaſt in ſome meaſure, what the *German Ephemerides* [p] have ſaid concerning a Hare. This famous Hare had two Heads, the one above the other; and eight Feet, four under the Belly, and four upon the Back.

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[p] Jour. des Sçav. 1677. p. 118.

When it was tired with running upon four Feet, the Writers of the *Ephemerides* made it run upon four others, till at laſt after having eſcaped many dangers by that means, it fell into the hands of a Prince.

Eudox. Probably Nature ſometimes produces theſe kinds of Monſters in order to furniſh variety of pleaſures to Princes, who only taſte thoſe that are innocent.

But finally, can theſe Animals, which have ſomething in them ſo ſurprizing, be only Machines? Can they have Reaſon?

Ariſt. One may read in the Journals of the Learned [q] of an artificial Horſe, which was capable of advancing ſeven or eight Leagues in a day upon a flat Field; and the Figure of a Man, an iron Statue, contrived by a Priſoner, which having gone out of the Priſon, went thro' ſeveral windings and turnings, to preſent upon its Knees a Petition to the King of *Morocco* in his Palace, and return'd to the Priſon [r]. And is it not ſaid that *Albert* the Great made a Head, which uttered ſome words? I don't warrant theſe Facts; but I have ſeen a Braſs-horſe, which by ſecret Springs turn'd about as Horſes do in the managing.

If the Induſtry of Men makes Machines of ſo ingenious a Structure, what cannot infinite Wiſdom do?

Eudox. Let us not limit Wiſdom that is without Limits. But a thouſand places of

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[q] Journ. des Sçav. 1680. p. 12.

[r] *Ibid.* 1683. p. 301.

Scripture ſeem to aſcribe ſome knowledge and paſſions to Animals. The Author of Nature has created us with a certain Biaſs, which leads us all to attribute thoſe things to them, and which, perhaps, inwardly contradicts any one who ſhould refuſe His aſſent. They have Senſes as well as we, and which bear ſome reſemblance to ours. The impreſſions which we receive thro' our Senſes, do not produce the motions of our Body without our Soul's being concerned in them We do not feel thoſe impreſſions in our Members, which of themſelves tranſport our Bodies toward ſenſible Objects. We do not perceive our ſelves forced to uſe the power of our Soul in order to ſtay the impetuouſneſs of the Body at the ſight of the moſt exquiſite dainties, even when we are preſſed with hunger. Upon what Principles ſhall we ſay then, that the ſenſible impreſſions received into Animals thro' Organs which appear ſo like thoſe of our Bodies, ſhould of themſelves tranſport their Bodies, without any Soul influencing them, in order to determine their motion?

Ariſt. We muſt then give reaſon to Animals?

Eudox. Faith teaches us that the Soul of Beaſts is not a Spirit. If animals had reaſon, the language of Parrots, and the thirty words pronounced by the *German* Dog, mentioned by M. *Leibnitz*, would have nothing in them ſo ſurprizing. It would be more aſtoniſhing that Animals do not ſpeak more to us, at leaſt by Signs. Reaſon would teach them to know us, and to explain themſelves better. We muſt always look upon Beaſts as Beaſts. They never had Reaſon. Therefore the different Species of Beaſts have nowiſe improved themſelves by time.

Ariſt. But, what is then the Soul of Beaſts? Is it the moſt ſubtile of Bodies? Is it extracted from the boſom of Matter? Or, is it I know not what modification of the Body?

Eudox. Matter which in its natural State is only an extended and impenetrable Subſtance, being only ſuſceptible of reſt, motion and figure; cannot feel, know, deſire, fear or ſuffer. Is it not more probable that the Soul of Beaſts is a Subſtance, which is really neither Spirit nor Body? A third Species of Subſtance only capable of ſenſible paſſions and perceptions, or of ſenſations, but exquiſite Senſations or Sentiments, which in practice are ſometimes equivalent to reaſonings, a Subſtance depending upon the Organs of the Body, uſeleſs without the Body; without reflections upon its perceptions, without deliberation, choice, liberty, or merit; and conſequently deſtined to periſh with the Body?

However that be; the Earth, Waters, human Bodies, Plants and Animals, are ſo many ſources of Meteors, elevated above our heads. Let us therefore, *Ariſtus*, diſpoſe our ſelves to carry our views a little higher.

CONVERSATION VII.

Upon Meteors.

Eudox. WITHOUT doubt, *Ariſtus*, you will give us, in the firſt place, a juſt Idea of Meteors.

Ariſt. The Meteors are Phænomena, which are obſerved in the Atmoſphere; as Exhalations, Vapours, Fogs, Evening Damps, Dew, White-froſt, Mildew, the Winds, Clouds, Rain, Snow, Hail, Thunder, the *Aurora Borealis*, the divers Fires which Nature kindles from time to time, and the Rain-bow.

Eudox. What a pleaſure is it to Philoſophers, to contemplate this admirable variety of Phænomena, and diſcover the Means which Nature employs, in order to afford this ſpectacle to the Univerſe!

Ariſt. I take a particular pleaſure in making ſome enquiry into the Thunder; and I ſhall communicate it to you, when you have informed me concerning the other Meteors.

Eudox. Some Letters, which I wrote, and of which I keep the original Copies, expreſs my Sentiments on this head.

LETTER I.

Upon Vapours, Exhalations, &c.

YOU ask my opinion of the nature, cauſes, and elevation of Vapours and Exhalations, of the Damp, Dew, White-froſt, Miſts, Rime and Mildew; here it is:

1. Vapours are aqueous Particles, which come out of the boſom of the Waters, and flutter in the Air. Thus Vapours re-united by cold, compoſe ſometimes thoſe ſpecies of Smoak which wet, and which you ſee riſe out of Wells, Rivers, Ponds, and the Sea; ſometimes ſenſible drops of Water, ſuch as one ſees in Summer upon Marble, upon the internal ſurface of Vaults, and upon pewter Veſſels full of freſh Wine.

As for Exhalations, they are particles which are exhaled from terreſtrial Bodies. Thus Rain-waters compoſed of Vapours, and impregnated with Exhalations, depoſite in the bottom of Reſervoirs a ſenſible Earth, whoſe parts form the groſſer Exhalations. Ordinary Exhalations conſiſt of volatile, nitrous, or vitrioline Salts. The moſt ſubtle of Oils or ſulphureous Spirits.

2. But what is it that cauſes and elevates Vapours and Exhalations *. The action of ſub-

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* It has been long obſerved, that in cloſe and rainy weather, the Quickſilver does not riſe ſo high, as when it is dry and clear; which has been thought by ſome to overthrow the whole Theory of the Weight of the Air; and indeed it is very difficult, to explain particularly the Cauſes of all the various and minute Changes of the Heavens; a great deal is owing to the Winds, which blow ſometimes upwards, ſometimes downwards, and ſometimes ſideways; a great deal to Vapours; a great deal to Steams riſing out of the Earth; ſomething muſt be aſcribed to the alteration of the Heavens in the neighbouring Countries, and perhaps ſomething to that *flux* and *reflux* which the Moon cauſes in the Air, which is much greater than that in the Sea, *&c.* To account for all which particularly and exactly, would be endleſs. However to propoſe ſomething which may come pretty near the Truth; it is to be obſerved, that the *Air it ſelf* is heavier than the *Vapours*, and fitted to ſupport them, becauſe its Particles are groſſer, and ariſe from denſer Bodies than the Particles of Vapours. In the firſt place therefore, this weight of the Air, *in any particular Country*, may be ſo changed by the *Winds*, that the Atmoſphere may be condenſed and made heavier, by bringing a greater Quantity of Air and heaping it together, *viz.* Whenever two Winds blow at the ſame time from contrary parts of the Heavens; or ſome of the Air may be carried or blown away by them, and thereby an opportunity given to the Atmoſphere to unfold itſelf, the incumbent Weight being taken off; *viz.* as often as two Winds blow from the ſame Country to oppoſite parts of the Heavens; or whenſoever any particular Wind is very ſtrong; for it is found by experience, that an artificial ſtrong Wind makes the Air lighter, and the Quickſilver in the Tube to fall very much. See *The Philoſophical Tranſactions*, Nº 292.

Secondly, *Cold and nitrous Particles of the Air* itſelf, *condenſed by cold from the North*, muſt condenſe the Atmoſphere whereever it comes, and make it heavier.

Thirdly, Heavy and dry Exhalations make the Air heavy (in the ſame manner as the ſpecifick Gravity of any Menſtruum is encreaſed, by diſſolving Salts and Metals) and its *elaſtick Force*, as it is called, muſt thereby become ſo much the ſtronger.

Fourthly, When the Air by theſe and ſuch like cauſes is become heavy, then it is more able to ſupport the Vapours, which when they are entirely mixt with it, and ſwim about, and are every ſubterraneous Fires and Heats, the Heat of the Sun, and Weight of the Air; and often the blowing of the Winds contribute to it. The action of ſubterraneous Fires or Hearts, agitates both the Waters and terreſtrial Bodies, divides, comminutes and fills their Particles, or ſurrounds them with ſubtile Matter; makes their Volumes lighter than an equal Volume of Air; impels, bears up, and makes them aſcend after the ſame manner as the Heat which penetrates the Bottom of an Alembic; makes the fine Particles of the Bodies which it encounters, to aſcend in Vapours or Exhalations. Hence thoſe who labour in Mines which are more than

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every way diſperſed in it, make the Sky ſerene and clear: But when the Air from contrary Cauſes, is made lighter, then is it unable to ſupport the Vapours with which it is always filled, and ſo being put into ſome ſort of violent agitation, they gather themſelves into Clouds and Miſts, and being formed into Drops, fall down.

From theſe Obſervations, it is very evident, that the ſame Cauſes which make the Air heavier, and more able to ſuſtain the Quickſilver in the Tube, make the Heavens alſo clear and dry; and by the ſame Cauſes, by which the Air is made lighter, and leſs able to ſuſtain the Quickſilver, are Showers and Rain produced alſo.

Hence it follows, Firſt, that when the Air is lighteſt, and the Quickſilver falls loweſt in the Tube, then the Clouds move very low and quick; and that the clear Air, which after Rain, appears between the thick Clouds, being diſcharged of its Vapours, ſeems moſt tranſparent and bright, and gives the beſt and eaſieſt proſpect of things at a diſtance.

Secondly, When the Air is more heavy, and the Quickſilver is raiſed higher in the Tube, then the Heavens are fair; but a little thicker, and not quite ſo blue, by reaſon of the Vapours which are every way equally diſperſed about; and, as has been by many obſerved, it does not afford ſo good a Proſpect of Things at a diſtance: and if there do appear any Clouds, they are very high than three hundred Fathoms deep, where the Heat of the Sun ſcarcely penetrating ſome few feet below the Surface of the Earth, has no acceſs, do nevertheleſs perceive Vapours and Exhalations, which ſometimes colour the Flame of a Candle.

Fermentations cauſed by the Heat of the Sun in Waters and terreſtrial Bodies, detach from them Vapours and Exhalations, and elevate them, as does the Action of ſubterraneous Fires and Heats. Wherefore Liquors expoſed to the Sun, are conſiderably evaporated; and between the Tropics, where the Heat of the Sun is moſt violent, the Vapours are ſo abundant

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high and move very ſlow; and when the Air is heavieſt of all, the Earth is ſometimes covered with very thick Clouds, which ſeem to conſiſt of heavier ſort of Exhalations, which the Air, at that time, is capable of ſuſtaining, but which cannot ſwim in lighter Air.

Thirdly, Hence it is, that in our own Country, when the Cold is greateſt, and the North and North-Eaſt Winds blow, the Quickſilver in the Tube is higheſt, becauſe at that time two Winds blow together upon our Country from oppoſite parts of the Heavens: for in the *Atlantick Ocean*, at the ſame *Latitude* with us, the Wind blows almoſt always from the Weſt. To which we may add, that the Air which is brought hither by the North Wind, comes condenſed by the Cold.

Fourthly, In the moſt Northern Countries, there is greater variation of the height of the Quickſilver in the Tube, than in thoſe Countries which are more South; becauſe in thoſe Countries, the Winds are ſtronger and more variable, and oppoſed by each other in a leſs Tract of Land; whence the Air is ſometimes more heaped up and condenſed, and ſometimes carried away and lightned.

Laſtly, Between the Tropicks, there is the leaſt Variation of all, in the height of the Quickſilver in the Tube, becauſe there the Wind is for the moſt part very gentle, and blows the ſame way. See *Philoſ. Tranſact.* N°. 181.

dant in the day time, that they fall again in Rain the whole night; which temperates the exceſſive Heat, and renders thoſe Countries habitable, notwithſtanding the burning Heat of the Sun.

When the Exhalations and Vapours are detach'd by the Fermentations, and encloſed or filled with ſubtile Matter, and are lighter in bulk, than an equal bulk of Air, the Air which ſerves it ſelf to detach them by its continual agitation, bears them up by the Action of its Gravity; almoſt as Water makes a Football full of Air aſcend by the exceſs of its Weight.

Finally, The Winds, which ruffle the Waters and dry the Earth, ought to carry off Vapours and Exhalations; and when, being reflected, they ſtrike againſt the Surface of the Exhalations or Vapours, ought they not to contribute to their Elevation?

3. Vapours and Exhalations, which riſe up and hover about on all ſides, produce after an imperceptible manner effects equally perceptible and ſurprizing. Often by reaſon of the Corpuſcles, which they carry off from all parts, they are the original of Diſeaſes. Oftentimes penetrating, like ſo many Wedges, Ropes and Wood, they ſtraiten the Ropes and ſwell the Wood; ſo that the ſtraitening of the Cords, or ſwelling of the Wood, is a Species of Hydrometer, that is, an Inſtrument fit for meaſuring the humidity of the Air.

There is alſo nothing more wanting than the imperceptible action of Vapours and Exhalations to cleave the hardeſt Rocks. What method is uſed to detach Mill-ſtones from Rocks, which have been cut out in form of a Cylinder? They make a number of Holes round about thoſe Rocks. They put into thoſe Holes pegs of Wood dried in an Oven. Theſe Pegs are diſpoſed all round, according to the largeneſs of the Mill-ſtones. In wet Seaſons, the Vapours and Exhalations inſinuate themſelves, like ſo many ſmall imperceptible Wedges, into thoſe more maſſy kind of Wedges, inflate, and ſwell them; being made larger, and forced to poſſeſs a larger Space, they cleave the Rocks, and detach the Mill-ſtones.

4. Should a mixture of Vapours, and eſpecially of Exhalations, elevated by the Heat of the Day, happen to cool again, to condenſate, and at laſt to fall down by its proper Weight after Sun-ſet, this is the Damp. There is no Damp in Winter, becauſe then the Heat is not ſtrong enough to elevate the Exhalations, which are terreſtrial, groſſer and heavier than Vapours. The Damp falls in the Spring, Summer and Autumn; and if it falls later in Summer than in the other Seaſons, the Reaſon is, becauſe in Summer the Cold neceſſary for condenſing, and rendring heavy the Exhalations, is later. Theſe Exhalations contain many ſharp and corroſive Corpuſcles, eſpecially in places where there are many Minerals. Wherefore

fore the Damp is often noxious, eſpecially to thoſe whoſe Pores are more open, and afford a freer acceſs to the Action of the Corpuſcles. Hence Defluxions, Tooth-aches, Hemorrhages, Head-aches, Watchings, Difficulties of Breathing, Oppreſſions; the ſad Conſequences of an agreeable Walk.

5. The Morning Dew, which contains fewer Exhalations, and conſequently is lighter than the Evening Damp, comes naturally after it. It conſiſts princpially of Vapours, which the Heat of the Day has not elevated very high, being condenſed by the Cool of the Night, and becoming perceptible by their being united together, toward the Morning, upon the Leaves and Flowers; where you ſee them ſuſpended, tranſparent and ſparkling, as a Species of ſmall Diamonds, wherewith the Poets ſay *Aurora* takes pleaſure to beſpangle the Meadows. Thus dry places, which afford no Vapours, are deſtitute of theſe poetical Riches. The Morning Dew requires a calm Air, and clear Sky; the Wind diſſipates it, and Clouds abſorb it. It is more frequent and abundant in Spring and Autumn, than in Winter and Summer; becauſe in Winter the Heat attracts fewer Vapours, and in Summer the Heat volatilizes them, raiſes them too high, and in ſome meaſure conſumes them.

6. Do the ſmall Drops, which make the Morning-Dew, happen to freeze by the Coldneſs of the Air? This is Froſt.

7. The Miſts are thick Collections of groſſer Vapours and Exhalations, which their Weight, or the Cold that condenſes them, hinders from riſing much above the Surface of the Earth, which they wet. The Cold, which unites the Vapours and Exhalations, renders the Miſts perceptible, as it makes the Breath and Sweat of Horſes perceptible in Winter, by re-uniting the Particles, which the Heat of Summer diſſipates, and does not ſuffer to be perceived.

Ordinarily one ſees Miſts ariſe out of Rivers, Valleys, and Marſhes; becauſe thoſe places have more aqueous Parts, and the terreſtrial Parts therein being leſs united, are detached and elevated more eaſily in Exhalations. Exhalations and Vapours that come out of muddy and marſhy places, ought ſometimes to be impregnated with ſtinking Corpuſcles. Thus Miſts, ſometimes, exhale a diſagreeable Odour.

8. Are the Miſts charged with nitrous or ſulphurous Corpuſcles, capable of tearing the Fibres of Plants, Ears of Corn, or Fruit yet tender? If theſe Corpuſcles happen to fall in ſmall Rain, it is Mildew. Mildew is attach'd to Plants; the Points of its nitrous and ſulphurous Corpuſcles ſink into and diſorder the Fibres, and hinder the Motion of the Juices; the Plants and Ears of Corn are dried up and fade away for want of Nouriſhment, and the Reaper at once perceives all his pleaſing hopes blaſted.

9. When the Rays of the Sun pierce the Miſt, the Heat rarefies it, the Rarefaction renders it lighter. Being lighter, it is elevated in a Cloud, or diſſipated. Sometimes the lighter Parts being ſeparated from the groſſer by the Heat, are loſt in the Atmoſphere, while the groſſer Parts fall down again upon one another, or near one another; and by being united, compoſe a Species of long and white Thread, which floats at the pleaſure of the Air, and to which they give the agreeable Name of the Hair of *Venus*.

Here, Sir, is my Opinion of the Vapours, Exhalations, both Evening and Morning Dews, white Froſts, Miſts and Mildew.

Ariſt. Vapours are, you ſay, Particles of Water; and Exhalations are terreſtrial Particles, elevated in the Air. The ſubterraneous Heats, the Heat of the Sun, the ſubtile Matter which contributes to the lightneſs of the Volume of which it makes a Part, the gravity of the Air, and the blowing of the reflected Winds; are ſo many Cauſes which may concur to the elevation of the Vapours and Exhalations. Do ſome imperceptible Exhalations, mixt with ſome Vapours, fall about Evening? It is the Evening Dew. Do imperceptible Vapours fall in the Morning, which make ſenſible drops by being united upon Plants, Leaves, and Flowers? It is the Morning Dew. Does the Cold of the Air lightly freeze the Dew? It is white Froſt. In a word, a thick Collection of Vapours and Exhalations that have riſen out of moiſt places, and are diffuſed in the Air, but detain'd near the Surface of the Earth by their Weight, or by the Cold, is what they call a Miſt. Certain nitrous and ſulphurous Salts, which the Miſt lets fall upon Plants, make the Mildew; and certain groſs Exhalations by being united, make this Species of white Thread, which one ſees ſometimes attach'd to Plants, and ſometimes flying at the pleaſure of the Wind. Theſe are Phænomena, *Eudoxus*, which your firſt Philoſophical Letter explains after ſuch a manner, as to give me a Taſte for the ſecond.

Eudox. Here it is.

LETTER II.

Upon the Winds.

WHAT is Wind? How many Winds do they reckon? What, is in ſhort, the Hiſtory of the Winds? What are the general Cauſes of Winds? Whence proceeds the different direction, the diverſity of Winds? From what ariſe the different qualities of Winds? Theſe are ſo many Queſtions, which you propoſe to me: I ſhall anſwer them in the ſame Order, and in few Words.

1ſt Queſtion. *What is the Wind?* It is a ſenſible Agitation of the Air, a ſenſible Tranſlation of the Air from one place to another.

The

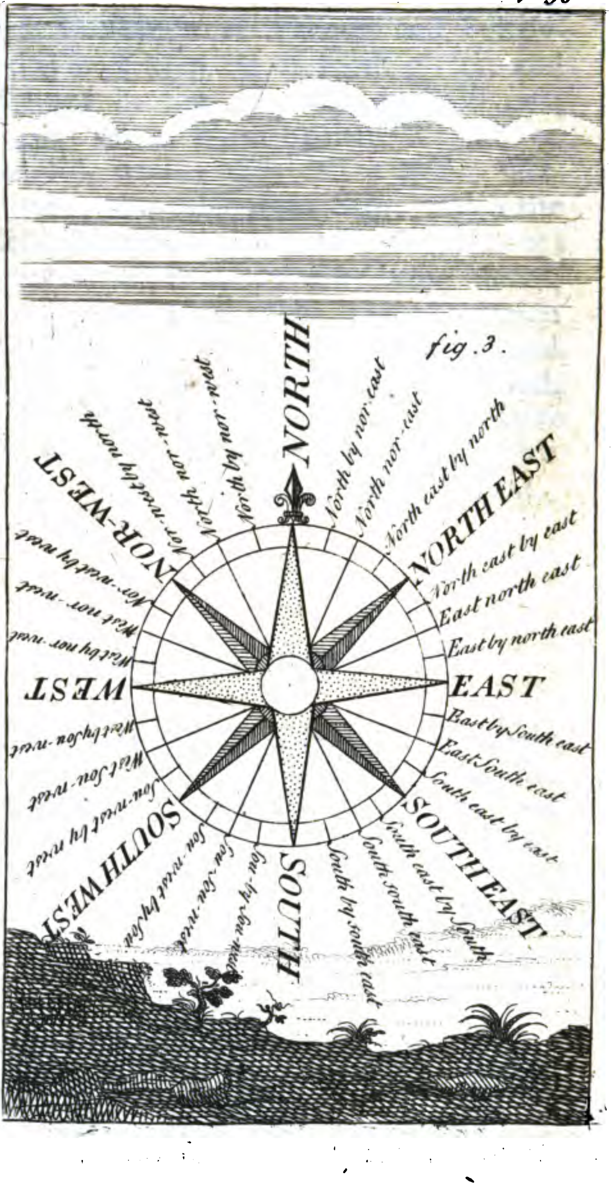

fig. 3.

NORTH
North by nor-east
North nor-east
North east by north
NORTH EAST
North east by east
East north east
East by north east
EAST
East by South east
East South east
South east by east
SOUTH EAST
South east by South
South south east
South by south east
SOUTH
Sou-by sou-west
Sou-Sou-west
Sou-west by Sou
SOUTH WEST
Sou-west by west
West Sou-west
West by Sou-west
WEST
West by nor-west
West nor-west
Nor-west by west
NOR-WEST
Nor-west by north
North nor-west
North by nor-west

The Fan, which the hand agitates, only ſenſibly agitates the Air; and it produces a ſmall cool Wind, a ſmall Zephyr, which conveys coolneſs.

2d Queſtion. *How many Winds do they count?* One may count as many as there are Points in the Horizon. Nevertheleſs, they only count thirty two; becauſe this number is ſufficient for determining thoſe which are uſeful in Navigation. Here are their Names and Situation in the following Figure, Fig. 3.

North, *South*, *Eaſt*, *Weſt*; *North-Eaſt*, *North-Weſt*, *South-Eaſt*, *South-Weſt*; *North-Nor-Eaſt*, *North-Nor-Weſt*; *South-South-Eaſt*, *South-South-Weſt*; *Eaſt-Nor-Eaſt*, *Eaſt-South-Eaſt*, *Weſt-Nor-Weſt*, *Weſt-South-Weſt*, *North by North-Eaſt*, *North-Eaſt by North*, *North-Eaſt by Eaſt*, *Eaſt by North-Eaſt*, &c. Names more uſeful than muſical.

The four firſt, namely, *North*, *South*, *Eaſt*, *Weſt*, are called *Cardinal*; becauſe they proceed from the Cardinal Points of the Horizon.

The four following, namely, *North-Eaſt*, *North-Weſt*, *South-Eaſt*, *South-Weſt*, are called Collateral; becauſe they are between the firſt. Every one of the collateral Winds is in the middle of two cardinal Winds, having their Name compoſed of the two Winds, in the midſt of which they are. Is it between *North* and *Eaſt?* It is called *North-Eaſt*. Is it between *North* and *Weſt?*

It is call'd *North-Weſt.* Between *South* and *Eaſt*, *South-Eaſt?* Between *South* and *Weſt*, *South-Weſt.*

The eight Winds following, every one of which is ſituated in the middle of a cardinal Wind and a collateral one, have a Name compoſed of the Names of both. Is the Wind preciſely in the middle of the *North* and *North-Eaſt?* They call it *North-Nor-Eaſt.* Is it in the middle of the *North* and *Nor-Weſt?* They call it *North-Nor-Weſt*, &c.

The laſt Sixteen take their Names, both from a cardinal Wind and from a collateral, to which they add the word *by*. The Name of every one begins with that of the Wind near which it is; and ends by the Name of the Wind, which is fartheſt diſtant from it. For example, the Wind which is neareſt to the *North*, paſſing toward the *North-Weſt*, is called *North-by-Nor-Weſt*; becauſe it is the fourth, counting from the *North-Weſt* to the *North*, *&c.*

3d. Queſtion. *What is in a few words the Hiſtory of the Winds?* Between the two Tropics, a continual Wind prevails, which blows inceſſantly from Eaſt to Weſt. There are other remarkable Winds between the Tropics, and ſuch as they call Trade-winds. The Trade-winds are the Winds of the North-Eaſt, and South-Eaſt, which are perceived between the Tropics. Without the Tropics, from the 23d Degree of Latitude to 40, they obſerve a Weſt-wind pretty conſtant; the Eaſt has its Trade-winds, which are periodical Winds, or which blow regularly from divers parts, according to the diverſity of the Seaſons. Such are thoſe Winds which reign in the Seas of *India*, and of *Arabia*, and which blow for the ſpace of ſix months from one ſide of the Horizon, and during other ſix Months from the other ſide. There are the Trade-winds of Winter, and others of Summer; they call thoſe Winter Trade-winds, which blow for about ſix Months from between the North and Eaſt. They call thoſe Summer Trade-winds, which proceed for ſix Months from between the South and Weſt.

There are few regular and periodical Winds, in compariſon of thoſe which are variable. Variable Winds are thoſe which blow ſometimes, and at other times blow not at all; which blow ſometimes from one Corner, ſometimes from another. The Winds, which are felt in theſe Countries, are almoſt all variable Winds. The Hurricanes are Winds, which carry Deſolation into the Countries which they paſs over. The Eaſt Wind is ordinarily dry with reſpect to us; the Weſt Wind rainy; the South Wind hot; and the North Wind cold. Finally, the Winds are ſometimes hurtful, ſometimes ſalutary.

The fourth Queſtion. *What are the general Cauſes of Winds?* The violent Eruption of Vapours and Exhalations, cauſed by ſubterraneous Fermentations; the Rarefaction of the Air by ſubterraneous Fermentations, or by the Heat of the Sun; and the Fall of Clouds.

The violent Eruption of Vapours and Exhalations. We cannot doubt the Winds iſſuing out of the Earth and Waters; they come from Caverns, Gulfs, and Abyſſes. There ariſes one out of the Mountain of *Malignon* in *Provence*, which extends no farther than the very Brow of the Mountain. There ariſes another in *Dauphiny* near to *Nilfonce*, which reaches a very ſhort way. Sometimes one ſees in a full Calm the Waters of the Sea ruffled ſuddenly round a Ship before the Sails are inflated; the Waves formed into Furrows, and driving one another toward ſome particular Side; then you perceive the blowing of the Wind.

Now, how are theſe kind of Winds formed? In order to comprehend this, one may compare the ſubterraneous Cavities to the Cavity of an Æolipyle*; the ſubterraneous Heats to thoſe of Fire, upon which they place the Æolipyle; and the Chinks of the Earth, the Caves, and Vents, thro' which the Vapours can get off, to the Hole of the Æolipyle. Place an Æolipyle upon the Fire, containing in it ſome Water; in a ſhort time the Water is evaporated; the Vapours iſſue out rapidly, being forced to paſs in a little time from a large Space into a ſmaller one, and protrude the Air; this rapid Impreſſion makes a ſort of Wind to be felt. After the ſame manner the ſubterraneous Fermentations and Heats, cauſe great Collections of Vapours and Exhalations to iſſue out haſtily from certain parts of the Earth and Waters, as ſo many Æolipyles. Theſe Exhalations and Vapours being thrown out violently, drive the Air according to the Direction which they have received in iſſuing out of the Earth or Waters. The Air being violently driven, communicates its Motion to the Air before it. Hence, this ſenſible Current of the Air, in which the Wind conſiſts; hence this Flux, this ſucceſſive flowing of the Air, which ſeems to imitate the Motion of the Waves, and makes the Puffs. In ſhort, ſometimes when the Weather is fair, and the Air calm, upon the *Garonne* near *Bourdeaux*, in the Lake of *Geneva*, and in the Sea, one ſees places bubble up ſuddenly, and the Bubblings followed with impetuous Winds, and furious Tempeſts; and *Fienus* ſays, that walking one day upon the Sea-ſhore, he ſaw a Miſt riſe out of the Waters like a ſort of Smoak, and that this Miſt was followed with a moſt terrible Storm. And what is it that produces the Typhons, thoſe Winds ſo dreadful in the *Indian* Seas? The ſubterraneous Vapours and Exhalations; for before the Typhons, the Waters of the Sea grow warm, the ſcent of Sulphur is obſerved, and the Sun is darkned[f].

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* Vol. 1. V. Converſ.

The Rarefaction of the Air. The Air being rarefied, whether by ſubterraneous Fermentations, or by the Heat of the Sun, cannot poſſeſs a larger Space, without driving away the adjacent Air; the Air being driven, flows towards the place where it meets with leaſt Reſiſtance; and if this flowing is ſenſible, it makes a Wind. Thus the Air of the Chimney, being rarefied by the Heat, produces in the Air, ſurrounding it a ſmall Wind, whoſe Motion is accelerated, and makes itſelf heard in the Interſtices of the Door or Windows of the Room where the Fire is made. Why is the Sun-riſing in Summer-time pretty often attended with a ſmall Wind? Probably it is the Effect of the Rarefaction of the Air cauſed by the Heat of the Sun, the Impreſſion of which makes itſelf felt even by us. After this, need we be aſtoniſhed, if a Wind reigns between the Tropics, which blows inceſſantly from the Eaſt toward the Weſt? The Rarefaction which the Heat of the Sun cauſes in the Air, Vapours, and Exhalations, with a Direction from Eaſt to Weſt, may produce this Phænomenon. Thus Mariners obſerve, that the Wind is ſtronger in the Day than in the Night[t].

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[f] Mem. de l'Acad. 1687. p. 261.

[t] Abregé de Gaſſ. T. 5. p. 188.

The Fall of the Clouds. The Fall of the Clouds being diſſolved by the Heat of the Air, and becoming more weighty, ſtrongly agitates the inferior Air; and this violent Agitation is a Wind, which laſts for a ſhort while, but is impetuous. This ſort of Winds are ordinarily followed with Rain; becauſe the Clouds whoſe fall produces them, are reſolved into Drops in their falling. Sometimes the Mariners perceive a Cloud over them, which at firſt appears very ſmall, becauſe it is much elevated, but ſeems to enlarge gradually, becauſe it deſcends and approaches, and whoſe fall upon the Sea is accompanied with Rain, Storm, and Tempeſt.

In a word, the height, largeneſs, and ſituation of Mountains, ſometimes ſtraitens the Paſſage of Vapours and Air agitated, and by that means cauſes an acceleration in their Motion. This Motion becomes ſenſible; and this is a real Wind. Thus, when Veſſels paſs along the Coaſts of *Genoa*, where there are high Mountains, and they are over-againſt ſome Valley, whoſe direction faces the Sea, there is felt a conſiderable Wind, which comes from the Land[u].

The fifth Queſtion. *Whence proceeds the different direction or diverſity of Winds?* From the different Situation of the Cauſes or Places whence the Impetuoſity of the Air proceeds, and of thoſe which reflect it. Bodies which move from a place, follow the direction which they received at firſt, until ſome obſtacle give them a new direction. Is the Neck of an Æolipyle toward the South? A Wind iſſues out of it, which proceeds from the North Point. Does this Neck lie Northward? A Wind iſſues out of it from the South Point. After the ſame manner the Direction of a Wind, which iſſues out of the Earth or Waters, anſwers to the Direction of the Vent thro' which it comes forth. In *Provence* there is a Mountain pierced thro' in the North and South part; from theſe two oppoſite Apertures proceed two oppoſite Winds; from the firſt a Wind, which diffuſes itſelf from the South toward the North; from the other a Wind, which blows from the North toward the South. According to the ſame Principle, does there happen in the Air ſome conſiderable Rarefaction on the South part? The lateral Air being impell'd by the force of the rarefied Air, flows towards the North where the reſiſtance is leaſt; and this is a South Wind. Does the Rarefaction happen on the North ſide? The Air being impell'd, flows towards the South; and this is a North Wind. Does a Wind encounter Heights, Mountains, and Clouds? It is reflected, making an Angle of Reflection almoſt equal to the Angle of Incidence. Hence a South-wind becomes a North-wind; a North-wind becomes a South-wind, *&c.* If Winds proceeding from divers parts happen to encounter one another, the weaker ought to give place to the direction of the ſtronger; ſince the greater Force prevails. Suppoſe a North or South Wind encounter a feebler Wind from Weſt or Eaſt, the feebler whirls about, and is abſorbed; and this is a Species of Whirlwind.

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[u] Regis. T. 2. p. 180.

We may now, I think, eaſily comprehend what concerns the Eaſt Wind, which reigns between the Tropics. This Wind ſeems not to be produced by the daily Motion of the Earth upon its Axis from the Weſt toward the Eaſt. For they find Calms in the *Atlantick* Sea near the Equator, and periodical Winds from the Weſt under the Equator itſelf. Whence then proceeds the Eaſt-wind, which reigns between the Tropics? In proportion as the Sun advances from Eaſt to Weſt, he dilates the inferior Air. The dilated Air propels the preceding Air, The thick and groſs Air, which follows the dilated Air, mixes itſelf rapidly with it, in proportion as the Sun retires. Hence the Eaſt-wind, which brings home our Veſſels loaden with the Riches of the Eaſt.

With the ſame eaſe one may comprehend the Trade-winds, the conſtant Weſt Wind between 23 and 40 Degrees of North Latitude, the Monſons in the *Indies*, the variable Winds, and Hurricanes.

1. The Trade-winds, or the Winds of the North-Eaſt and South-Eaſt, which blow between the Tropics, depend upon the different

Rarefaction of the Air cauſed by the different Situation of the Sun, which produces greater Rarefactions under the Tropics than under the Equator; becauſe toward the Tropics he is longer above the Horizon. The Trade-winds being reflected obliquely by the mountainous Coaſts of *America*, make the conſtancy of the Weſt Wind, which blows without the Tropics. 2, The Monſons in the *Indies* depend, as well as the other Trade-winds, upon the different ſituation of the Sun, which rarefies the Air more, elevates the Vapours and Exhalations more, when he is more perpendicularly over a Country, and gives them different Directions, according as he is differently ſituated. 4. Irregular Fermentations produce the variable Winds. 5. Should the Action of ſome ſubterraneous Fire, or of ſome violent Fermentation, ſhoot out a great Quantity of Vapours and Exhalations obliquely into the Air; ſhould a thick Cloud happen to fall obliquely from on high; the Air charged with Exhalations and Vapours, and impell'd forward by an extraordinary force, ſpreads itſelf, flows rapidly, following the Direction which it hath received, agitates and over-turns whatever it encounters, Trees, Buildings, and Houſes; and this is an Hurricane.

Water-Spouts are probably cauſed, like the moſt part of Hurricanes, by ſubterraneous Fermentations. Theſe Water-Spouts are Pillars of Smoak, which ariſe out of the Sea

At firſt one ſees the Water bubble up. Then a black Smoak is thrown out and elevated, with a hollow Noiſe, like that of a Torrent. If a Veſſel encounter it, the violence of the obſcure Column burſts the Sails. Sometimes it bears up the Veſſel itſelf: the Veſſel being born up, falls down again quickly by its weight; and its Motion being accelerated in the Fall, buries it in the Waters, while the Column continues to elevate itſelf by whirling about rapidly, and is loſt in the Clouds. When the Mariners perceive the Danger, they ſhoot off ſome Guns' charged with Bars of Iron, in order to drive off the dreadful Column to ſome diſtance by the impulſion of the Air, or to cut and diſſipate it, by diſperſing the Water which compoſes it [*].

6th Queſtion. *Why are Winds dry or wet, hot or cold, hurtful or ſalutary? Whence proceed the different qualities of Winds?* The greateſt part of them proceed from divers Corpuſcles, which they carry off with them, according to the divers Regions, out of which they ariſe, or thro' which they paſs. Are the Winds but little charged with Vapours? They are dry. Hence Eaſt Winds, which paſs thro' a great tract of Land, and but little Sea, are ordinarily dry. Do Winds bear along with them plenty of Vapours? They are wet. Hence Weſt Winds, which paſs thro' a length of Sea, are ordinarily rainy. Do Winds come from hot Countrys? They are generally hot; becauſe they bring along with them Vapours, Exhalations, or Particles of Air agitated with that univerſal Motion, which makes heat. Hence South Winds are ordinarily hot. The cold of the ſevere Winter in 1709, appear'd to be for ſeveral Days the effect of a South Wind; but the Mountains which are on the South of *Paris* were at that time covered with Snow, and this South Wind could be nothing elſe but a reflux of a North Wind, which had preceded [y]. Do Winds proceed from cold Countries? They are commonly cold; becauſe they bring along with them Particles which have only a direct Motion, or which contain in them plenty of Salts, Nitre and Icicles, which certainly contribute to render the Winds cold. In ſhort, put ſome ſmall Icicles, at the vent of a pair of Bellows, a colder Wind iſſues out. Hence the North Wind is ordinarily cold. Finally, Winds are hurtful or ſalutary, according as the Corpuſcles with which they are charged in different Parts, are hurtful or ſalutary. Here is, Sir, my Sentiment concerning the Winds.

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[*] Journ. des Sçav. 1682. p. 133. 27 Avril, & p. 205. 29 Juin.

Ariſt. But when a South Wind has blown, why is it not always immediately followed with a North Wind? The Air, I think, ought to flow back, there being no *vacuum*; do not the Elaſticity and Æquilibrium of the Air require it?

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[y] Hiſt. de l'Acad. 1709. p. 9.

Eudox. The Air ought to flow back, but it may do ſo below our Hemiſphere, or thro' the ſuperior region of the Air; or elſe make a circuit, and return through ſome place which allows it a freer ſpace for extending itſelf.

Ariſt. Do you believe, *Eudoxus*, that the Winds explained after this manner produce the Currents of the Sea?

Eudox. The Currents of the Sea, which are as it were Species of Rivers in the middle of the Sea, ſeem to me to depend upon ſubterraneous Rivers in the bottom of the Sea, interrupted by Rocks, Iſlands and Winds. There are perpetual Currents; ſome are regular, or ſuch as without being perpetual, are formed at certain Seaſons, and in certain Places. Some of them are periodical, or ſuch as carry the Waters ſometimes to one ſide, ſometimes to another; and ſome are variable. Perpetual Currents probably proceed from certain ſubterraneous Rivers, which are emptied into the Sea. Other Currents proceed from this, that the Waters being driven by the Winds, are reflected by Iſlands, Lands and Rocks, or are more ſhut up in certain places than others, becauſe there are Iſlands or Rocks parallel, which ſtraiten the paſſage of the Waters, and conſtrain them to accelerate their Motion. The regular Winds produce periodical Currents; and variable Winds, variable Currents.

Ariſt. Here is, I think, in few words your Sentiment of the Winds. 1. Wind is in general a ſenſible Tranſlation of the Air from one place into another. 2. They reckon up 32 Winds; four Cardinal, four Collateral, *&c.* 3. Subterraneous Fermentations, the Heat of the Sun, the Eruption of Vapours and Exhalations, the Rarefaction of the Air, and the Fall of Clouds are the Origin of Winds. 4. The different Direction of Winds proceeds from the different Situation of the Parts whence they come, or by which they are reflected. 5. The Winds have different qualities, according to the Corpuſcles, and the Agitation of thoſe Corpuſcles which they carry along with them. 6. The Eaſt Wind, which blows continually between the Tropics, proceeds from the exceſſive Rarefaction of the Air between the Tropics; the Trade-winds from the inequality of Rarefaction in the Air under the Tropics and Equator; the conſtancy of the Weſt Wind in certain Countries, from the Reflection of the Trade-winds, cauſed by the Mountains of *America*; the different Monſons in the *Indies*, from the different ſituation of the Land of *Aſia*, and of the Sun; and the Hurricanes, from the violent fall of ſome Cloud, or from ſubterraneous Fires. 7. Irregular Fermentations produce variable Winds. Finally, upon variable Winds depend variable Currents; upon periodical Winds, periodical Currents; and upon regular Winds, regular Currents.

I eaſily enter, *Eudoxus*, into your Sentiment; and the Clouds, which I ſee carried at the pleaſure of the Winds, double my earneſtneſs of knowing what you have written upon Clouds, Snow, Rain, and Hail.

LETTER III.

Concerning the Clouds, Snow, Rain and Hail.

Eudox. SIR, After one knows what concerns Vapours, Exhalations, Miſts, and Winds, it is eaſy to comprehend what relates to Clouds, Snow, Rain and Hail.

Clouds are a collection of Vapours and Exhalations ſuſpended in the middle Region of the Air; and whoſe thickneſs obſcures the Heaven. In ſhort, Clouds differ but little from Miſts, only in this, that they are lighter and more elevated. Thus, thoſe who aſcend the *Alps* and *Pyrenees*, or high Mountains of *Hungary*, when they arrive at the Clouds, imagine to themſelves that they are entring into a ſort of Miſt.

Clouds are formed by the rencounter of Exhalations and Vapours, by cold, and by the action of Winds. The Vapours and Exhalations which happen to touch one another, are hooked together in the ſhock, loſe their Motion, and reſt near one another; the Cold condenſes them in the Atmoſphere, as it condenſes them upon the interiour Surface of the Head of an Alembick; and the Action of the Winds re-unites them. All theſe Cauſes concur to produce thoſe Maſſes extended over our heads, which ſhutting up the Paſſage of the Sun-beams, withhold the Heaven from our Eyes.

That which makes the Exhalations and Vapours to aſcend, as Fermentations, the Gravity of the Air, and the blowing of the Winds, elevates alſo the Clouds. The Clouds are more or leſs elevated in proportion to their Gravity, the Gravity of the Air, and the Strength and Situation of the Winds, which blow from below upward. Wherefore, during Summer, the Clouds are ordinarily farther diſtant from the Earth, becauſe containing more igneous Particles, they are more rarefied and lighter.

But what is it that holds the Clouds ſuſpended in the Air? The igneous or ſubtile Matter, which ſurrounds the Exhalations and Vapours, or which is contained in them, the Air, the Winds which come from the Earth, and the Expanſion it ſelf of the Clouds, all theſe contribute to it. The igneous or ſubtile Matter, renders the Volume of the Cloud lighter, and in a better condition of being ſuſtain'd by the Weight of the Air. The Winds which blow from below upward, ſuſtain it. The Expanſion of the Cloud gives it a large Surface in regard of its Maſs, and is the Cauſe why the inferiour Air cannot give place, unleſs a large Volume of Air give place at the ſame time. This large Volume of Air cannot give place at the ſame time, without being forced to go with a very great Velocity, in order to reach the Extremities of the Cloud. Now the exceſs of Gravity, which may be in the Cloud, is not ſufficient to communicate this exceſs of Velocity to the inferiour Air. Hence the inferiour Air reſiſts, and ſuſtains the Cloud for the ſame reaſon, as Water, which does not ſuſtain a golden Ball, ſuſtains the ſame quantity of Gold extended into a very thin Leaf. The Reſiſtance of a Body, anſwers to the Velocity neceſſary for its yielding.

Finally, Clouds are more or leſs obſcure, in proportion as they contain more or fewer Exhalations and Vapours; becauſe then the Light finds more or fewer Paſſages *. According to the divers Changes which the Clouds cauſe in the Light, they have different Colours; they are blue, white, red. If they are of unequal Weight, they are elevated above one another. Are the Vapours and Exhalations, which compoſe the Clouds, united together in divers parts? Are they of unequal Gravity, and differently agitated by the Winds? You ſee Clouds of different ſhapes. Sometimes the Heaven appears beſtrewed with ſorts of Fleeces; ſometimes they are as it were Ridges of Mountains and Rocks, which bound the Horizon, and proceed by degrees to loſe them-

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* See *Notes* Converſat. XXII. Vol. II.

ſelves in a red or blue Heaven, and make Proſpects, admirable Landskips, and Points of View inimitable by the Art of the Painter.

Should a frozen Cloud happen to be diſſolved by its own proper Weight, or by the Impreſſion of the Winds? It falls down in Flakes, which are compoſed of ſmall globules of frozen Vapours, and faſtened together by ſmall Threads of Exhalations; and this is Snow. Snow conſiſts in Flakes, which are a texture of ſmall globules of frozen Vapours; ſuch almoſt as one ſees in Hoar-froſts, and faſtened by very minute Threads of ramous Exhalations.

Snow is about five or ſix times lighter than Water, ſince being melted it is ordinarily reduced to a fifth or ſixth part of the Height which it had[a]: Becauſe the Interſtices of the Globules, which compoſe the Snow, are full of Air, and the Bonds which attach them are very minute. They are, I ſay, very minute, ſince cold Water diſſolves Snow. Snow is formed in a more elevated Region than that where Rain is formed: for Rain melts Snow, and one ſees the top of high Mountains covered with Snows, which Rain does not diſſolve. Commonly when Snow is ready to fall, and when it falls, the Cold diminiſhes. Probably the Cloud, which bears Snow, drives back the Exhalations which come from the Earth, and the Exhalations by that means acquire this univerſal Motion, which makes Heat. Finally, Snow contributes to the Fecundity of the Earth; becauſe it retains Exhalations, and brings along with it Spirits of Nitre, which being joined with the Exhalations, nouriſh and cheriſh the Plants.

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[a] Hiſt. de l'Acad. 1711. p. 16.

If the Cloud is not frozen, or if it is melted by the Heat of the Earth or Sun, and diſtils in ſmall Drops; the ſmall Drops are re-united in their Fall, become ſenſible; and the ſenſible Drops make Rain *. Rain conſiſts in the perceptible Drops which fall from the Cloud. The higher they fall, the groſſer they are; becauſe in their fall they are re-united in greater number. Thus ordinarily in Summer, the Drops are larger than in Winter. Generally the Months of *June*, *July* and *Auguſt*, alone furniſh as much Rain as all the other Months together[a], becauſe the Heats of *June*, *July* and *Auguſt* elevate many more Vapours and Exhalations.

Would you have ſome certain Preſages of Rain? The Stars, Animals, and Barometer will furniſh you. When the Light of the Moon or Sun is pale, the Stars ſparkle, the Doors make a greater noiſe than uſual, the Ants retire, and Swallows fly near the Earth, or the Barometer is low; you may be afraid of Rain, the Air is impregnated with groſs Exhalations and Vapours. In ſhort, the groſs Vapours and Exhalations uſually diffuſe a certain Paleneſs over the Sun and Moon, and render the Light of the Stars more twinkling, by virtue of their interrupting the Rays. They ſwell the Wood, fill up the Interſtices. Hence, the Doors are opened with greater difficulty, and make more noiſe. The Ants retire, becauſe the leaſt Moiſture renders their way almoſt impracticable. The Swallows graze upon the Earth probably in order to lay hold on the little Inſects, which the Humidity makes to deſcend. Are not the Prognoſtics of the Barometer the moſt certain *?

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* The moſt effectual Cauſe of Rain is the weakening of the Elaſticity of the Air. *See Notes*, p.

[a] Hiſt. de l'Acad. 1696. p.406.

Laſtly, When Rain, or Snow almoſt melted, falling from on high, encounters in the Atmoſphere with a cold Wind, or ſome place full of Salts, Nitre, Saltpeter, it freezes †, and this is Hail. Hail is only a Species of frozen Rain. In its fall it may encreaſe in bulk by virtue of its encountering with Vapours, which attach themſelves to it, and in their being attach'd are turned into Ice. But, why falls there leſs Hail in Winter than Summer? Becauſe in Winter, the Clouds not riſing ſo high above the Horizon, the Snow falls before it

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* Converſat. XXII. Vol. I.

† As Water in a Veſſel in the Summer-time is immediately turned into Ice, by externally applying Salt and Snow. See *Philoſ. Tranſact.* N°. 231.

it is melted, or the Rain before it is turned into Ice. *I am*, &c.

This is my Judgment concerning aqueous Meteors; you will favour me with yours, *Ariſtus*, in another Converſation, concerning igneous Meteors.

CONVERSATION VIII.

Upon Thunder.

Eudox. I AM impatient, *Ariſtus*, to hear you diſcourſe of Thunder. This is a Subject whoſe Name alone ſpreads Terror, but which will have nothing in it but Pleaſure for me, while I hear you diſcourſe of it like a Philoſopher.

Ariſt. When one knows, *Eudoxus*, what you have told me concerning Fermentations, Exhalations, Winds and Clouds, it is eaſy to ſpeak of Thunder as a Philoſopher. Sometimes they diſtinguiſh the Thunder from the Thunderbolt, and they take Thunder for the Noiſe alone. Sometimes they confound the Thunder and Thunderbolt, and all Men ſeem ſo to do, when they ſay that the Thunder is fallen. For my part, I confound the Thunderbolt and Thunder; and I diſtinguiſh the Lightning and the Noiſe from the Thunder and Thunderbolt.

This being granted; What is Thunder*? Thunder is only a mixture of ſulphurous, bituminous and ſaline Exhalations, enflamed in ſome Cloud. For, 1. Thunder is an inflammable Matter, imperceptibly elevated from the Boſom of the Earth into an upper Region, where it is enwrapt in ſome gloomy Cloud; which perfectly agrees with ſuch Exhalations. 2. Thunder is inflam'd as of it ſelf. Ought not a Mixture of thoſe Exhalations to ferment and be inflamed after that faſhion? We ſee in chymical Operations, an acid Spirit, with the eſſential Oil of an Aromatic Plant; for example, the Spirit of Nitre, with Oil of Cloves, two cold Liquids, to be inflamed at once as of themſelves. 3. Thunders are ſo much the more frequent in a Country, the more Exhalations of this nature the Earth therein furniſhes. 4. In places, where Thunder is fallen, they commonly perceive a ſcent of Sulphur and Bitumen; and would the Flame of the Thunder be ſo violent, if it did not contain volatile, nitrous, ſulphurous, and vitrioline Salts, or others fit for ſhooting out on all ſides? Laſtly, One always conceives Thunder or the Thunderbolt, as a Fire contained in a Cloud, or darted into the Air from the Boſom of a Cloud.

Horace probably had a mind to droll like a merry Philoſopher, when he ſaid that they had ſeen *Jupiter* with the Thunderbolt in his hand, in a calm and clear Sky. Sometimes one ſees the Lightnings, and hears the Thunder roar, in fair weather; but the Cloud, which bears the Thunder, is hid under the Horizon. The Exhalation which is not ſhut up in a Cloud, would be diſſipated in the Inflammation without any crack, almoſt like Powder kindled in an open ſpace. Therefore Thunder is a mixture of ſulphurous, bituminous and ſaline Exhalations, inflamed in certain Clouds.

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* See *Notes* Converſat. III. Vol. II.

Eudox. Let us ſee deliberately, *Ariſtus*, how the Thunderbolt * ought to be formed according to your Principles, to be kindled, to produce Lightnings, and this terrible noiſe which follows them, to dart itſelf into the Air, to flutter about at the pleaſure of the Winds, to ſtrike the tops of Mountains, to cleave or eradicate Trees, to throw down Edifices, to melt Metals, to ſpare the tendereſt Bodies, to deſtroy more ſolid ones, and to affect, if I may ſay ſo, to glance upon them ſometimes without hurting them, *&c.* I ſhall only preſent you with the Thunderbolt, and the Species of Miracles, which it operates in Nature; you will diſcover to me the ſecret Cauſes and Springs. In the firſt place, in time of heat the Thunderbolt is formed in the Cloud.

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* No ſuch thing in Nature: the Miſchief occaſioned by Lightning, is to be attributed to its force being collected together.

Ariſt. The Heat agitating terreſtrial Bodies, the Bodies of Animals, and Minerals, detaches from them ſulphurous, bituminous, nitrous, vitrioline Exhalations, *&c.* Theſe Exhalations being detached by the heat, and born up by the weight of the Air, and the blowing of the Winds, are elevated into a colder Region, loſe of their motion, are re-united and condenſed in the Clouds; and this is the matter of the Thunderbolt or Thunder. Thus, as we have already obſerved, in hot Countries, and where the Sulphur, Bitumen, Nitre, Salt-petre, and Vitriol are in greater quantity, Thunder is much more frequent.

Eudox. At once the matter of the Thunder is enflamed, as of it ſelf, in a cold Cloud.

Ariſt. The Shock of the Clouds kindles it, the Action of the Winds, the Heat of the Sun, or rather the Mixture of heterogeneous Spirits. There is nothing that takes fire more eaſily than Sulphur, and Bitumen, which burns even in Water. Theſe oily Bodies are full of ſubtile and fine matter, continually agitated with rapidity. Some farther degrees of agitation ſtill, and all their Particles, have this univerſal Motion, which makes the Flame. The ſhock of the Clouds, and the blowing of the Winds, are capable of adding theſe degrees of Agitation; and why may not the heat of the Sun, direct or reflected, do the ſame? We know that a moderate heat inflame inflames the *Pulvis fulminans*. Likewiſe nothing more is required than a certain mixture of Exhalations, to cauſe an inflammation without the help of a foreign Fire; ſince a mixture of citrine Aqua-fortis, with the eſſential Oil of an aromatic Plant, takes fire of it ſelf. And M. *Lemery*, of the Royal Academy of Sciences, having hid in the Earth about 50 pounds of a Mixture compoſed of equal parts of Sulphur and Filings of Iron, tempered with Water; after 8 or 9 hours the Earth vomited out Flames [b].

Eudox. The moment of the Inflammation, the Lightnings are darted out of the Cloud.

Ariſt. The ſudden and tranſitory Inflammation of the Exhalation, produces in the etherial matter, which ſurrounds it, and which it agitates, ſudden and momentary Flames, which ſtrike the Eyes briskly; and theſe are Lightnings.

Eudox. But if it is an inflamed Exhalation, which produces Lightnings, the ſame Exhalation muſt be inflamed ſeveral times, in order to produce that great number of Lightnings, which we often ſee iſſue out of a Cloud. Now can the ſame Exhalation be inflamed ſeveral times? A mixture of Liquors once inflamed in the Laboratory of our Chymiſts, is never kindled again.

Ariſt. A mixture of Liquors once inflamed in our Chymical Operations, is inflamed no more; why? After the Materials, of which it is compoſed, are once inflamed, and conſequently become very rare and light, the inferior Air more weighty than they compreſſes them, and elevates them into a ſuperior Region, where they are loſt to us. But are the ſame Materials elevated in Exhalations from the boſom of the Earth, as far as this upper Region? The Cold re-unites them, and after this re-union, they do not remain ſuſpended, but becauſe they are ſuſtained by the blowing of the Winds, or becauſe they make with the ſubtile Matter ſmall volumes as light as the Air; or elſe, becauſe all together they compoſe one entire Volume, which has ſome exceſs of ſurface in proportion to its maſs. Therefore they may be rarefied in the Inflammation, as M. *Homberg* has obſerved[c]; and may be in equilibrium with the fine Air which ſurrounds them. This being granted, why may they not be inflamed at ſeveral times? After Inflammation, altho' they be more ſubtile, yet are they ſtill in equilibrium with the Air in which they float. Conſequently they may remain therein, and be re-united. The Spring of the Air being compreſſed in the Inflammation, and dilated again, draws them near one another again; the Vapours, in which they are encloſed, ought to contribute to retain and re-unite them, and their agitation makes them encounter one another.

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[b] Hiſt. de l'Acad. 1700. p. 574. Mem. p. 102, 103.

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[c] Hiſt. de l'Acad. 1708. p. 2.

Hence, the ſame Exhalations make new Mixtures; new Mixtures make new Inflammations, and new Inflammations make thoſe repeated Lightnings, which we ſee iſſue out of the ſame Cloud.

Eudox. Theſe repeated Lightnings are ſometimes like ſo many broken fiery Darts.

Ariſt. When the Fire of the Thunder contracted in a Cloud, forcibly bends the Spring of the ſurrounding Air, this Air by that means becoming capable of reſiſting it, is dilated, and contracted at different times, throws it back rapidly for ſeveral times ſucceſſively, and only lets us ſee broken Darts of Fire.

Eudox. Theſe Flaſhes of Fire threaten us with a Clap of Thunder.

Ariſt. When the Exhalation is compreſſed in the Cloud, the Inflammation, which produces thoſe briſk Flaſhes, violently dilates the Air contained in the Exhalation and Cloud. The dilated Air compreſſes the neighbouring Air; the bended Air unbends it ſelf, communicating its alternate motion to the Air diffuſed as far as us. Hence the trembling of the Air, which makes a dreadful noiſe, being prolonged and redoubled by the Echo's of the Valleys and Mountains, as it were with Emulation.

The Action of the Sulphur and Bitumen, wrapt up in Vapours diſſolved by the Inflammation, ought to contribute to the Thunderings, like Iron plunged into Water. Some

Phænomena that are pretty ſingular ſeem to confirm my Opinion. At *Queſnoy* the fourth of *January* 1717, the Weather being very cloudy, they ſaw in the middle of the Place, in a Cloud which ſeemed to touch the Houſes, a Globe of Fire, which broke itſelf againſt the Tower of the Church, with the Crack of the Shot of a Gun, and ſpread itſelf over the Town like a Shower of Fire [d]. 2. The ſeventh of *January* 1700, the Inhabitants of *Hogue* in lower *Normandy* ſaw a Fire in the Air, which had the ſhape of a Tree, and ſeemed to fall and loſe itſelf in the Sea with a noiſe, which made two large Villages ſituated upon the Sea-coaſt to tremble [e]. 3. M. *Lemery* mixed 3 Ounces of the Spirit of Vitriol with 12 Ounces of Water; when the Mixture was warmed a little, he ſtrewed into the Veſſel, at ſeveral times, an Ounce and half of the Filings of Iron. Immediately ſome white Exhalations iſſued out of it, which were lighted with the Flame of a Wax-Candle; and they became a kind of Lightning and Thunder [f]. Finally, the noiſe of the *Pulvis fulminans* heated, and which is only a Mixture of Sulphur, Salt-petre, and Salt of *Tartar* [g], imitates and makes the noiſe of the Thunder ſufficiently underſtood.

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[d] Mem. de l'Acad. 1717. p. 8.

[e] Hiſt. de l'Acad. 1700. p. 10.

[f] Hiſt. de l'Acad. 1700. p. 575.

[g] Converſat. I. Vol. II.

Eudox. Nevertheleſs, it ſometimes thunders without Lightning.

Ariſt. 1. In Chymical Operations, which are performed ſtill better in the Clouds than in our Laboratories, there may happen a ſort of cold Fermentations, as in Mixtures of Vinegar and Coral; and this ſort of Fermentation never fails to make a noiſe without any Inflammation. 2. A Cloud diſſolved by the heat may, in falling upon another, and compreſſing the Air intercepted between the two, produce a noiſe like that of Thunder, without kindling the Exhalations. 3. May not the Baſis of the Cloud be ſo thick, that it deadens the Effort of the Inflammation, and withholds it from the Eye?

Eudox. All Lightnings ought at leaſt to be followed with a Clap of Thunder.

Ariſt. The Inflammation is ſometimes too weak to agitate the Air ſenſibly, becauſe the Sulphurs of the inflamed Mixture are deprived of Salts, which are the principal cauſe of the noiſe. Beſides, as Gun-powder is kindled without noiſe in a free ſpace, becauſe in that caſe its forces do not act at the ſame time, nor are ſufficiently united for making the effect conſiderable; after the ſame manner an Exhalation too free, or which is not ſufficiently contracted, is kindled without Thundering. The Thunder is only a Species of Gun-powder inflamed.

Eudox. But when the Thunder-clap breaks out, why does it follow the Lightning, tho' the Clap and Lightning proceed from the Cloud at the ſame time?

Ariſt. Becauſe the etherial Matter which bears the Light, conveys the Impreſſion which it hath receiv'd more ſwiftly, than the Air which conveys the Sound; becauſe the etherial Matter is finer, and is not compreſs'd, whereas the Air is groſſer, and is compreſs'd: Becauſe the Motion of Light is direct, and that of Sound undulatory.

Eudox. The Clap, which follows the Lightning, is ordinarily followed with a Shower of Rain.

Ariſt. The Inflammation, which cauſes the Noiſe, ought naturally to ſhake and diſſolve a part of the Cloud, and make it fall down in Rain.

Eudox. When the Rain abounds, it ſcarcely thunders any more.

Ariſt. Becauſe the Water which falls upon the Exhalations, drowns it, if I may ſo ſay; or carries it off, at leaſt in part.

Eudox. But juſt now, *Ariſtus*, the Queſtion is about darting out the Thunderbolt, or ſeeing it iſſue out of the Cloud. Ought it not always to aſcend, receiving ſome exceſs of Levity in the Inflammation?

Ariſt. The Weight of the condens'd Exhalation, which is only inflam'd and conſum'd ſucceſſively, the exceſs of Reſiſtance which it meets with in the upper part of the Cloud, deeper and colder, a Vortex of diſſolved Vapours which ſurrounds it, being formed by the Inflammation; all this gives the Exhalation a Direction toward the Earth, and precipitates it like a Species of Rocket turned topſy-turvy.

Eudox. Should you ſee it iſſue out of the Cloud, you would believe you ſaw divers Fires ſhoot out at the ſame time.

Ariſt. Becauſe the Exhalation iſſues out in ſeveral parts, or the Reſiſtance of the Air ſeparates it.

Eudox. What long Tracts of Fire! Do they touch both the Earth and Cloud at the ſame time?

Ariſt. The ſtrong Impreſſion which a Vortex of Fire makes upon the Eye, when it is darted out of the Cloud, ſubſiſts ſtill, even when it is removed to a diſtance from it, and makes it to appear where it is not, as the Impreſſion of a burning Torch, rapidly agitated, makes it to be ſeen where it is not, preſenting to the deceived Eyes a long Train of Fire.

Eudox. The Fire of the Thunder turns round in its Fall, and deſcribes a broken Line.

Ariſt. Becauſe the Center of Gravity is not in the Center of Figure, and the different Parts of the inflamed Exhalation do not ſtrike the Air with equal Forces. This is what makes it to go winding about in ſome ſort, like ſmall Squibs which they throw in the Air.

Eudox. Do you believe that the Exhalation always reaches the Earth?

Ariſt. When it is too light, ſo that it has not Matter enough to furniſh Nouriſhment to the

Flame, or is not ſufficiently compreſs'd, it ought to be diſſipated in the Atmoſphere. Beſides, the Air, neareſt to the Earth, being more groſs, has the more force to reſiſt, and conſequently it may often happen, that the Exhalation being repell'd, aſcends and is diſſipated without reaching us.

Eudox. But how can that, which comes to us ſwifter than the Wind, obey the Wind?

Ariſt. A Body impell'd by different Impreſſions, but ſuch as are not diametrically oppoſite, complies with each in proportion to its Force. Wherefore, when I obſerve that the Wind can give the Thunderbolt a Direction toward my Cloſet, I ſhut it exactly; my Philoſophical Conſtancy is the leſs mov'd on that account; and I philoſophize a little more calmly upon the Nature and Effects of Thunder.

Eudox. The Thunderbolt very rarely happens to ſtrike Men. It ſeems to avoid them deſignedly, and to attach it ſelf to greater Objects; to Trees, great Towers, and the top of Mountains.

Feriunt ſummos Fulmina Montes *.

Ariſt. The Thunderbolt only follows the Laws of Phyſicks in this. For, 1. Bodies, which are more elevated, may cleave the Baſe of the Cloud, or force the Wind to carry off the Baſe of the Cloud by ſtraitning its Paſſage, and by that means facilitate the Fall of the Exhalation upon them. 2. The Exhalation encounters them ſooner in its fall. 3. Such an Exhalation may reach them, as would be diſſipated for want of Fuel, before it reach us. 4. Could the Exhalation reach us; ſometimes a reflected Wind, which makes it fly over our Heads, carries it upon the Top of a Tree, Tower, or Mountain.

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* Horat. Od. Lib. 2. Od. 10. V. 11.

Eudox. But, *Ariſtus*, are Trees cleft or rooted up, Bellfries uncovered, and Edifices thrown down, the Effects of an Exhalation?

Ariſt. The Cold cleaves Trees; may not an inflamed Exhalation dilate them ſo as to cleave them, eſpecially when it is carried in a Whirlwind, which alone cleaves Trees, breaks, or roots them up ſometimes, acting againſt the Branches as againſt ſo many oppoſite Leavers, twiſting about, and making the Trunk of the Tree turn round? An impetuous Wind uncovers Bellfries; therefore an Exhalation, groſs and more rapid than the Wind, may likewiſe do ſo. In ſhort, an Exhalation, which with an almoſt infinite Velocity happens obliquely or horizontally to ſtrike againſt a Wall, which it calcines, inſinuating itſelf into the Interſtices of the unhewed Stones, where is acts as Powder in a Mine, may detach the Stones ſo much the more eaſily, becauſe in that caſe it has not their Gravity to overcome. The efficacy of a Body in Motion anſwers to the Velocity; and ſome Stones below being carried off, the Wall falls down, and the Edifice is overturned. If the Exhalation be ſhut up, with its Vortex of

Water or Vapours, between two Walls of an Edifice, much after the ſame manner as Gunpowder kindled in a Mortar-piece, or in a Mine, the Walls being violently puſh'd on one ſide by the Effort of the Exhalation, without being equally ſuſtain'd on the other, follow the Impreſſion of the greater Force, burſt, fall down, and are diſſipated, as happens in a Mine.

M. *Deſlandes*, an ingenious Philoſopher, whom Curioſity carried into a Village, whoſe Church had been entirely burnt down by Thunder, ſays, that in this Village ſituated near *Breſt*, they had ſeen three Globes of Fire of three foot and a half in Diameter each, and that they were united together; that this large Vortex of Flame had come rapidly, and pierced thro' the Church two foot above its level with the Ground; that it had inſtantly killed two of the four Perſons who were Ringing, and made the Walls and Roof of the Church to ſpring as a Mine would have done: ſo that the Stones, were confuſedly ſcattered round about, ſome of them being carried twenty-ſix Fathoms, and others ſunk more than two Foot into the Earth *.

Eudox. I am no longer ſurprized that the Thunder, when it falls in a cloſe place, as a Room or Church, melts Metals, breaks Steel, and produces at once a number of different Effects.

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* Hiſt. de l'Acad. 1719. p. 22.

Ariſt. The Flame of an Enameller's Lamp being driven, like a ſmall Dart, by the Blaſt of a Bellows, very quickly melts Glaſs and Metals. Is it ſurprizing that the Fire of Thunder, much more rapid, melts Metals in the twinkling of an Eye? The Flame of Sulphur penetrates them at firſt; a piece of Sulphur being applied to ſome Steel red-hot in the Fire, reduces it to Powder. The variety of Effects produced at the ſame time, proceeds probably from this, that the Exhalation, which is not of a very ſtrong Conſiſtence, is divided into many inflamed parts by its encountering with a hard Body. Thus ſometimes there have been ſeen three or four ſmall ſeparated Flames flutter about in a Room *.

Eudox. I ſhould be more aſtoniſh'd if the Thunder ſhould diſſipate your Silver in your Purſe, and your Sword in the Scabbard, without hurting either Scabbard or Purſe, and that you ſhould get rid of it for ſome Piſtoles, and ſome Fright; or if it ſhould drink up the Wine in the Cask, without piercing or hurting it.

Ariſt. Such like Facts are the Sport of the Thunder, or rather of the Imagination. Nevertheleſs, perhaps, they are not ſo impoſſible as they may appear to be. We ſee Salts ſpare the moſt tender Bodies, while they diſſolve the hardeſt. Spirit of Nitre neither diſſolves Wood nor Wax, and yet it changes Iron into a Species of Liquor. From a mixture of Lime, Vinegar, common Salt, Nitre, and Sulphur, they extract a Salt which penetrates Iron, without cauſing in it any ſenſible Alteration[h].

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* Mariotte, de la percuſſion des corps, p. 224.

From bituminous Matter they extract a Salt, which imperceptibly paſſes thro' the Pores of a Plate of Silver[i]. The *Menſtruum*, which finds a free Paſſage thro' a Body, makes no change in it. Can it paſs thro' without ſome difficulty? It penetrates forcibly, agitates, ſhakes and diſſipates the Particles which oppoſe themſelves to its Paſſage. Cannot a light and ſubtile Exhalation act after the ſame manner in the Purſe and Silver, the Sword and Scabbard? May it not penetrate the Cask without hurting it, as bituminous Liquor penetrates Silver? May not the Wine being heated exhale imperceptibly like new Wine?

Eudox. Probably you will believe me, *Ariſtus*, if I tell you that the Thunder one day paſſed between the Shirt and Skin of a young Man of my acquaintance, and that it did nothing to him except making a Trace on his back without hurting him.

Ariſt. Since the Flame of Spirit of Wine runs upon Linnen and the Hand, without burning either Hand or Linnen, why may not an inflamed Exhalation, almoſt ſpent, be ſo weak that it paſs between the Shirt and Skin without burning them?

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[h] Mem. de l'Acad. 1713. p. 308.

[i] Ibid. p. 310.

Eudox. You will not ſurely, *Ariſtus*, allow the Thunderbolt to be a Stone.

Ariſt. A Stone does not kill without Contuſion, as the Thunderbolt does, whoſe Sulphur ſometimes ſtops the Paſſages of Reſpiration, and ſuffocates without any perceptible mark of a Wound.

Eudox. Although the Thunder be only an Exhalation, it is always terrible. What Means can be uſed to turn it aſide? I diſcern a gloomy Cloud; and I hear a true Thunder roar.

Ariſt. The ringing of Bells, and the noiſe of a Cannon agitating the Air, repels or turns aſide the Cloud which is advancing, and turning aſide the Cloud, it diſperſes the Thunder which the Cloud bears along with it.

Eudox. Nevertheleſs the Noiſe ſeems ſometimes to attract the Thunderbolt. For in *Lower-Bretany*, on the Night of the 14th or 15th of *April* 1718, in that part of the Coaſt which extends from *Landerneau* to St. *Paul* of *Leon*, the Thunderbolt fell upon twenty four Churches in which they were ringing. The neighbouring Churches, in which there was no ringing, were ſpared *.

Ariſt. The Noiſe ſeems to attract the Thunderbolt: but that is when it happens under the Cloud, becauſe then the Air being ſtrongly agitated, divides, agitates and weakens the Baſe of the Cloud, and by that means facilitates the Inflammation and Eruption of the Thunder, which being darted out through the weakeſt part, falls vertically, or almoſt vertically upon the place from which the Noiſe proceeds. Thus ſlow and imprudent Ringers are often ſtruck with Thunder. A Misfortune which they might prevent, if they were as good Philoſophers, as they are zealous for the publick Good.

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* Hiſt. de l'Acad. 1719. p. 21.

Eudox. Conſequently it is of importance to know, at leaſt nearly, at what diſtance the Thunderbolt is; but by what means may it be eaſily known?

Ariſt. By obſerving how often the Pulſe beats between the Lightning and the Noiſe. If it beat ſix times, the Thunderbolt is about 6000 Paces diſtant. Five times? 5000. Four times? 4000. Three times? 3000, *&c.* For the Sound which comes ſucceſſively, and from that part where the Thunder is, comes off at the ſame time with the Lightning; and according to the Experiments of the Royal Academy of Sciences, it advances about a thouſand Paces during the beating of the Pulſe, or in one Second. Wherefore, ſhould the Noiſe immediately follow the Lightning, the Thunder is near; a Philoſopher himſelf fears, if he is ſuſceptible of fear. The Danger is preſſing, or rather it is paſt; for the fall of the Thunderbolt is as quick as the Lightning. He who fears Thunder, ſays *Seneca*, has nothing to fear *:

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* Quæſt. Natural. l. 2. c. 59.

Nemo unquam fulmen timuit, niſi qui effugit.

Eudox. This heartens me, *Ariſtus.* And to prevent the Thunder, which we have juſt now heard from intimidating Philoſophers; you ſhould have explained to me your Sentiment upon the other Fires, which have been obſerved in the Atmoſphere. But let us go and ſup together; we ſhall talk of the News of the times; and then go and take the Air and divert our ſelves in a philoſophical manner, by diſcourſing of the fallen Stars, *Ignes fatui*, Columns of Fire, and that *Aurora Borealis*, which has appeared ſo often of late Years, and ordinarily five or ſix hours at leaſt before the Sun.

CONVERSATION IX.

Upon fallen Stars, Ignes fatui, and the Aurora Borealis.

Eud. AT laſt, there is no more Thunder nor Cloud; what Pleaſure! I acknowledge, *Ariſtus*, that there is no Spectacle more affecting to a Philoſopher, than the Heaven all ſparkling with Stars. Does it not grieve you to ſee one of them fall juſt now, leaving behind it a long train of Fire? Here is exactly what *Virgil* foretold us *:

Sæpe etiam ſtellas, Cœlo impendente, videbis
Præcipites Cœlo labi, noctiſque per umbram
Flammarum longos a tergo albeſcere tractus.

Ariſt. The Heaven will not ſhine the leſs for that. This Species of Star is only a light Exhalation, almoſt wholly ſulphurous, which is inflamed in the free Air, much after the ſame manner as Thunder in a Cloud, by the blowing of the Winds, or by the action of the ſubtile Matter, and an Acid in the Sulphur. The ſuperior part of the Exhalation kindles firſt, becauſe it is lighter; ſince it is more elevated, it is alſo more inflammable. The Inflammation is communicated to the inferior part of the Exhalation, as in a train of Powder. Hence, this ſort of Star ſeems to fall. And becauſe the Communication happens ſo rapidly, that the Inflammation is in the Baſe of the Exhalation, when the Impreſſion, which it makes upon the Eyes, yet ſubſiſts, we fancy we ſee a long train of Fire, which is properly no where elſe but in our Mind.

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* Georg. l. 1. v. 365.

Eudox. Thoſe Fires which repoſe themſelves, or flow gently upon the Hair of Children, and of which *Virgil* alſo ſpeaks*:

Ecce levis ſummo de Vertice viſus Iüli
Fundere lumen apex, tactuque innoxia molli
Lambere flamma comas, & circum tempora paſci.

The *Ignes fatui*, which ſport upon the ſurface of the Earth, and which ſeem to fly from thoſe who do not fear them, and to purſue thoſe who do; the Fire *St. Elme*, which faſtens to Maſts and Sail-yards of Veſſels after ſome Tempeſts; thoſe Fires more elevated in the Atmoſphere, and which they call Columns, Pyramids, horizontal Light, or elſe the Northern Aurora, *&c.* Theſe are ſo many

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* Virg. Æneid. l. 2. v. 682.

Exhalations kindled almoſt after the ſame, manner, as that Star which juſt now fell.

Ariſt. We are, I think, equally perſuaded of it.

M. *Bernier* ſays [a], that one Night, in a ſtifling Heat, among the Iſlands of the *Ganges*, he ſaw in the Thickets all ſhining with Glow-worms, ſome Fires which aſcended every moment, ſometimes on one ſide, and ſometimes on another; that two of them appeared extraordinary, of which the one was as it were a large Globe of Fire, and the ſecond like a Tree in flames. What were thoſe Fires, if not Exhalations?

A light Exhalation, coming out of the ſubſtance of a Man, may reſt upon his Head, and ſhine without burning, almoſt like a Glow-worm. The *Ignes fatui* are Exhalations which proceed from Church-yards, and other ſulphurous places, where there happens a Fermentation. In ſhort, nothing is more common than theſe Fires in the Torrid-Zone. You would ſay that they ſport, when they flutter about at the pleaſure of the agitated Air. If they fly from you, when you advance, that is becauſe you puſh the Air forward which bears them. If they ſeem to purſue you, when you run away from them, the reaſon is becauſe the Air which bears them, takes poſſeſſion of the place which you quit every moment. The Fire *St. Elme* is only a viſcous Exhalation, kindled upon the Sea by the Shock and Agitation of the Salts. Is an Exhalation, more extended, elevated, and lighted in the Atmoſphere, but in a free Air, is it, I ſay, cylindrical? It is a *Column*. Is it terminated in an angular Point, having a large Baſe, in form of a Pyramid? It is a *Pyramid*. A Collection of inflamed Columns and Pyramids in a luminous and tranſparent Cloud, which is often obſerved toward the North, is what they now call an *Horizontal Light*, but formerly *Aurora Borealis*, becauſe of its reſemblance with the Morning-Star in brightneſs. Was not the name of *Aurora* fine enough? But what think you, *Eudoxus*, of the Northern Light?

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[a] T. 5. p. 155.

Eudox. You may ſee, *Ariſtus*, in a Letter which I wrote, and of which I keep a Copy. It is ſomewhat long.

Ariſt. I ſhall find it too ſhort.

A Letter upon the Phænomenon of the 19th of October, 1726.

SIR,

ON occaſion of the Phænomenon, at which all *Paris*, except the Philoſophers, were aſtoniſhed, the nineteenth of this Month, and which the *French* Gazette juſtly calls a Northern Light: you demand my

Sentiment concerning what they call this Northern Light.

It is a Species of thin, tranſparent and luminous Cloud, which appears from time to time, upon the Horizon, in the night towards the North. Formerly they called it *Aurora Borealis*, becauſe of its reſemblance to the Morning in clearneſs.

At preſent it is ſometimes an Horizontal Light, ſometimes a Northern one. It has loſt the ſpecious Name of *Aurora*, probably becauſe it generally precedes the Morning it ſelf five or ſix hours at leaſt. However that be, they have obſerved this Light in ſeveral Ages; but eſpecialy in our days. They obſerved it in 992 [b], 993, 1621, 1707. And this Meteor has appear'd frequently all the following Years, from 1716 to 1726 [c]. They ſaw the ſame Species of Meteor, but with ſome difference in the Apparitions. In 992, on *Chriſtmas* Night, you would have taken the Night itſelf for Day. In 993, on St. *Stephen's* Night, there was a kind of Morning-break. In 1621, on the twenty firſt of *September*, M. *Gaſſendi*, being near to *Aix* in *Provence*, ſaw on the North ſide a luminous Cloud, which poſſeſs'd 60 Degrees of the Horizon, between Eaſt and Weſt [d]. It was elevated in form of a Bow, more than 40 degrees high, and darted out white and red Pyramids and Columns. In 1707, the ſixth of *March*, there were Species of Rain-bows, out of which iſſued ſome luminous Rays, directed toward the *Zenith*; Phænomena uſual in *Greenland*, *Norway* and *Iſeland*, and almoſt continually in Countries near the Pole [e]. In 1716, the fifteenth of *March*, they perceived a Light toward the North-eaſt, whoſe Baſe was embattel'd, and the upper part terminated in the form of a Spear, of the colour of Fire; and diſtinguiſhed by ſundry white Channellings, thro' its whole length. The ſeventeenth of the ſame Month, at *London*, they ſaw northward a kind of Gulf of reddiſh Light, which darted out its Rays from time to time, like lighted Rockets. Theſe Rockets ſpread themſelves, and formed Waves in the Air of a clear Smoak, but ſo tranſparent, that they ſaw the Stars thro' them, and ſo bright, that they diſcerned the Houſes. M. *Maraldi*, who has exactly obſerved thoſe Phænomena ſince 1716, has ſundry times ſeen a great horizontal Light, whitiſh, like a tranſparent Twilight, and which permitted him to ſee the Stars. But in the Month of *April* 1716, the Columns aſcended, ſays he, like Rockets, and one would have thought that they were ſo many Spouts of Light. The thirtieth of *March* 1719, they ſaw a Column of Fire elevated 20 degrees above the Horizon, between the North-nor-Weſt and Weſt, parallel to the Horizon, and extended 25 or 30 degrees. It obſcured the Light of the Moon, altho' the Moon was in the eighth day, and very clear. People were affected with this Phænomenon, and a cry of Admiration was raiſed throughout all *Paris*. The eleventh of *February* 1720, M. *Maraldi* ſaw more Columns of Light, which had ſomething in them ſtill more affecting.

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[b] Calviſius. Recueil d'Obſervations, par M. de l'Acad. des Sciences.

[c] Hiſt. de l'Acad. 1716. p. 6. 1717. p. 3. 1718. p. 1. 1719. p. 1. 1720. p. 4. 1722. Mem. p. 1. 1726. p. 3.

[d] Abrege de Gaſſendi, tom. 5. p. 245.

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[e] Gaſſendi, tom. 2. p. 100. Recueil d'Obſervations, par M. de l'Acad. des Sciences.

After all, Sir, I doubt whether before the Phænomenon of the nineteenth of this Month, any thing had been obſerved more marvellous toward the North, than what I ſaw at *Flèche* in *Anjou* the firſt of *March* 1721. Three quarters of an hour after ſeven a-clock in the Evening, I perceived on the North-ſide a tranſparent Cloud, which was extended almoſt from the North-eaſt to the North-weſt; and ſeemed elevated from the North Horizon almoſt to the Pole. It was like an *Ellipſis*, whoſe ſmall Diameter almoſt anſwered to the Meridian of *Flèche*. The Cloud appeared extraordinary to me. Near eight a-clock, I ſaw five luminous Columns ariſe ſuddenly on the part of the Eaſt. Three of them were diſſipated quickly, and the two other, which were very long and perpendicular to the Horizon, paſt toward the Weſt, ſometimes ſtopping, ſometimes recoiling; then again continuing toward the Weſt, flowing always upon the meridional Arch of the Cloud. Such kind of Columns were formed from time to time in divers parts. The Heaven was very ſerene. Half an hour after eight a-clock, a part of the luminous Cloud divided it ſelf into different ſmall Clouds, carried toward the South. But a little before nine they were united again to the great Cloud, and in this re-union I ſaw a great number of very bright Columns. At nine the Cloud was inflamed from the Eaſtern border to the Weſt part; ſo that I ſaw a prodigious number of Rays, Cones, Pyramids, and Columns of Fire, which darted out on all ſides. Many of thoſe Columns ſeemed to bound over my Head. Their Flame was very gentle, white, and mixt with blue. In proportion as thoſe Fires iſſued out of the boſom of the Cloud, eſpecially on the South part, there were hollow ſlopes made in it; ſo that in a very little time, the South part ſeem'd gnawed to the Center. The inflammable Matter which came from the Eaſt part, filled up this Vacuity; and the ſame ſport begun again toward ten. We ſaw the Matter of the Phænomenon ariſe inceſſantly above the Horizon toward the North-eaſt, always from the ſame place. It ſeem'd ſometimes to ſpread itſelf by Undulations; and now and then ſeeming Waves, flowing into certain obſcure parts of the Cloud, were quickly inflamed. A quarter of an hour after ten, the Center of the

Cloud ſeemed diſſipated by the Inflammation, almoſt as far as the North Horizon. After this, I ſaw nothing more remarkable. This Phænomenon attracted the Attention of the whole Country.

The Phænomenon, which appear'd lately, has ſomething in it ſtill more aſtoniſhing, at leaſt as to its Extent. About a quarter of an hour after ſeven in the Evening, they ſaw on the North ſide of *Paris* two Species of luminous Arcs, the one above the other, which extended from the Weſt even beyond the North-eaſt, or from the Weſt toward the Summer Sun-riſing. The greateſt of thoſe Arcs was elevated above the Horizon, almoſt 25 degrees, and ſent off now and then ſome ſmall Columns of a very white light. But toward eight a clock, ſuch a prodigious quantity of Beams, Columns and Globes of Fire iſſued out of the two luminous Arcs all at once, that the Heaven was almoſt wholly covered with them, excepting about the height of 30 degrees toward the South. The Light formed a kind of Crown and Dome toward the *Zenith*. On the Weſt part they ſaw a Cloud of a very bright red. They ſaw one much like it toward the Eaſt, but not ſo red. The Heaven ſucceſſively aſſumed different Colours, which ſpread themſelves over the Clouds. The Phænomenon laſted 'till ten a clock in its Splendor, with ſome changes however, ſometimes more feeble, ſometimes more luminous. After that, it recovered its vigour again from time to time; and they affirm [*], that the *Aurora Borealis* appeared ſtill toward the North, when the true *Aurora* ſhewed it ſelf in the Eaſt.

This Phænomenon [†] ſpread terrour abroad. As for you, Sir, I don't believe that you are diſpoſed to take thoſe celeſtial Fires for Battles pitched in the Air, or Prognoſtications of ſome fatal Event. The new Philoſophy has annihilated the greateſt part of thoſe Battels and Prognoſtics. The Fires, which the cold Climates of the North ſend us from time to time, are only Exhalations inflamed above the ordinary Clouds, but however within the Atmoſphere. Theſe Fires, I ſay, are elevated above the ordinary Clouds, ſince ſometimes thoſe Clouds happen to withhold them from our Eyes. Nevertheleſs they are in the Atmoſphere. In ſhort, they do not participate of the regular Motion of the Stars from the Eaſt toward the Weſt, as M. *Maraldi* has obſerved. They are not inflamed Exhalations; for one ſees them aſcend above the Horizon, and to be inflamed in proportion as they aſcend, when the Sun and Moon are for a long time below the Horizon. But why does the luminous Cloud appear ſloped or dented, in proportion as the Rays, Pyramids, Columns, or Globes of Fire are darted out of its Boſom?

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[*] Mem. de l'Acad. 1729. p. 207.

[†] Obſervé en divers endroits; à l'Obſ. par M. Godin.

Doubtleſs becauſe the Exhalation being attenuated and diſſipated by the Rarefaction, which happens in the Inflammation, becomes imperceptible.

Exhalations of this kind are probably ſulphurous, bituminous, and nitrous Exhalations. We are no longer allowed to doubt, whether ſuch Exhalations can take fire as of themſelves, without the Aid of foreign Fire. There is nothing that kindles more eaſily than Sulphur and Bitumen. Theſe oily Matters have a thouſand ſmall Cells full of Air, whoſe Spring is always bent, and of a ſubtile Matter, always rapidly agitated. Some farther degrees of Agitation; and the Particles of the ſmall Cells being broken, will have this quick and univerſal Motion, which makes the Flame to ſparkle in our Eyes. The blaſt of the Winds, or the rencounter and ſhock of Clouds, may add thoſe degrees of Agitation, and cauſe the Inflammation. I have often ſeen, in the Northern Light, ſmall Clouds inflamed by encountering one another. Neither is there any thing more required, to produce thoſe ſudden Inflammations, than an Acid in ſome ſulphurous Matter. Mix a little Gun-powder with Oil of Cloves, pour upon this Mixture ſome citrine Aqua-fortis; you ſee at once a Flame of Cones and Globes of Fire iſſue out of the Mixture of two cold Liquors, and Gunpowder kindle, when one only pours Aqua-fortis upon it.

In proportion as the Exhalations are thus inflamed in the Air, according to the different Figures, different Conſiſtence of the inflammable Matter, and the divers Reflections or Refractions of Light, one ſees Rays, Cones, Globes, Pyramids or Columns of Fire iſſue out, under different Colours, from the luminous Cloud. If the Light is white, the reaſon is becauſe the Exhalation contains no Vapours. The Vapours afford a red colour to the Light. That of the Sun is commonly conſiderably white, when he is much elevated; and red, when he is in the Horizon; becauſe when he is in the Horizon, his Rays paſs through more Vapours. Vapours afford very free Paſſages to a great quantity of Rays, but many Rays are ſtopt by the ſolid parts of Vapours. Free and lively Rays, but interrupted or mixt with Shade, diffuſe a red colour over Objects *. Probably the two Clouds of a bright red, which they obſerved in the late Phænomenon in the middle of a white Light, contained plenty of Vapours.

But the Spouts of Light, ſometimes white, ſometimes red, or blue, which ſhoot out like Lightnings from the boſom of the Cloud, ought they not to be followed with ſo many Thunder-claps? Lightnings, which foretell Thunder-claps, are cauſed by the Inflammation of an Exhalation compreſſed in a thick Cloud. Wherefore, the forces of the inflamed Ex-

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* Vol. II. Converſat. XXIII.

halation being re-united by the reſiſtance of the Cloud, and acting almoſt all at once, like thoſe of Powder kindled in the Mouth of a Gun, ſtrongly bend the Spring of the Air, and produce in the Air this alternate Motion, this impetuous Tremulation, which makes the noiſe, which the Echo's of Mountains and Rocks redouble and prolong. But the Inflammation of a rare, light, and free Exhalation ought not to cauſe this crack, becauſe its forces are ſucceſſively diſſipated, and are not ſufficiently united. By the ſame Principle, Gun-powder is alſo inflamed quietly and without noiſe, in a free ſpace. Now, the Exhalation of a luminous Cloud is a rare, light, and free Exhalation, ſince it is tranſparent and elevated above the ordinary Clouds: Therefore theſe Fires ought not ordinarily to be accompanied with noiſe, as Lightnings are.

But finally, why are theſe Fires ſo frequent toward the Pole, and commonly proceed from Northern Countries? In the matter of Phyſics, it is allowed to venture upon ſome Conjectures, eſpecially when one only offers them as Conjectures. Sometimes the leaſt probable happen to be true, as the moſt probable are found to be falſe. The Vortex of magnetic and fine matter, which they make to circulate from one Pole of the Earth to the other, after M. *Deſcartes*, in order to direct the Poles of the magnetic Needle toward the Poles of the Earth, is ſtill at leaſt probable. What is it, pray, which gives the Needle this Direction, if not an inſenſible Matter, which has the ſame Direction? The Needle has it not of it ſelf. It is only a ſmall portion of Matter without Efficacy. Now this Vortex iſſuing out from the Pole, and thoſe adjacent Countries, abundantly and impetuouſly, ſhould it not carry off with it an extraordinary quantity of ſulphurous and bituminous Exhalations, filled with this fine Matter, which might render them lighter and more inflammable? Proceeding from Northern Climates, they ſhould render the Phænomena almoſt continual there, as they are. Being light, they ſhould be elevated, as they are, above ordinary Clouds; and a blaſt of Wind ſhould carry them; as one ſees them carried, ſometimes Southward, ſometimes Eaſtward, and ſometimes Weſtward. Being abundant, they might cover, as they did lately, a great part of the Heaven, and from time to time preſent to our eyes Spectacles, which ſpread terror amongſt the Populace, the moment that they divert Philoſophers, the undiſturbed Spectators of a Heaven all on fire.

Nevertheleſs, a fact more certain, than my Conjecture, is that I have the honour of being, with profound reſpect,

Sir,

Your moſt humble, &c.

From Paris, 28
Octob. 1726.

This, I think, is the *Aurora Borealis* ſet in its full light.

Eudox. The Rain-bow, tho' it often preſents itſelf to our Senſes, will perhaps have in it ſomething ſtill more entertaining and curious. You have already ſufficiently made known to me your Sentiment upon this head *. I will now tell you mine.

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* Converſat. XXII. Vol. II.

CONVERSATION X.

Upon the Rain-bow.

Ariſt. I Always find new pleaſure in conſidering the Rain-bow, its Figure, and the Arrangement and Variety of its Colours. But this pleaſure is not equal to that, which you give me in diſcovering the ſecret cauſes of it, according to your Principles.

Eudox. In order to explain my ſelf upon this Phænomenon, I begin with ſome Obſervations.

1. They call the Iris or Rain-bow, thoſe different Colours, diſpoſed in form of a Bow, much like thoſe of a Priſm, and perceptibly ſpread over ſome Cloud oppoſite to the Sun.

2. When we have our Backs turned toward the Sun, and ſquirt out Water with the Mouth, or look upon the ſcattering of the Drops of a Water-ſpout, we obſerve the Rain-bow pretty well imitated upon the diſperſed Drops. Wherefore, I diſtinguiſh two Rain-bows, the

one artificial, the other natural. Art contributes to form the firſt; Nature alone forms the ſecond. Such is the Bow deſcribed on a Cloud oppoſite to the Sun, and with which only our buſineſs is here.

3. Sometimes only one Rain-bow appears; ſometimes one ſees two at the ſame time, one internal, and the other external. Each of theſe Bows has three principal Colours; Red, Yellow, and Blue, which give riſe to the other Colours.

4. In the internal Arc, the Blue is below, the Red above, and the Yellow in the middle. On the contrary, the external Arc has the Red inwardly, and the Blue outwardly.

5. I give to the viſual Rays the name of the Colours, where they terminate. Hence, I call them red, yellow, or blue Rays.

6. The Line drawn from the Center of the Sun to the Center of the Iris, which paſſes thro' the Eye of the Spectator, I call the Axis of Viſion, as they commonly do.

7. In the internal Arc, the viſual Rays make with the Axis of Viſion, Angles of about 41 degrees 14′; the yellow Rays, Angles of 41 degrees 30′; and the red Rays Angles of 41 degrees 46′. In the external Arc, the red Rays make Angles of about 51 degrees 46′; the yellow Rays, Angles of 52 degrees; and the blue Rays, Angles of 52 degrees 16′ *. Let us firſt conſider only the internal Arc.

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* According to the Calculation of M. *Rohault*. 3 part. chap. 17.

This being granted, what makes the Rain-bow? The Rays of the Sun more or leſs broken in the Drops of Rain, and reflected to our Eyes with Vibrations more or leſs ſtrong, and with more or leſs ſhadow. 1. The Rays of the Sun; for Colours are only Light modified, and the Iris does not appear but when the Sun enlightens the Horizon. 2. Theſe Rays are broken, ſince almoſt all of them fall obliquely upon the ſpherical ſurface of the Drops, and the Rays, which are only reflected, do not give different Colours to Water. 3. They are, I ſay, Rays broken in Drops of Rain: One ſees no Rain-bow but only in rainy Weather. 4. Theſe Rays are reflected to our Eyes, ſince they convey to them, from the part of the Air oppoſite to the Sun, the impreſſions of different Colours. And this is done with Vibrations more or leſs ſtrong, and with more or leſs ſhadow; for the Rays, which come from the ſuperior part of the Arc, being leſs broken, ſince they make a larger Angle with the Axis of Viſion, and the Angle which they make with the direct Rays anſwers to this Angle, have loſt leſs of their force: Conſequently, they ſtrike our Eyes with ſtronger Vibrations. But as they are in the Convexity of the Arc, they are ſo much the more mixt with ſhadow, becauſe they are nearer the ineffectual Rays. The Rays that come from the middle of the Arc being a little more broken, but between the red and the blue, which ſuſtain them, are a little feebler, but leſs interrupted, and leſs mingled with ineffectual Rays. Hence, the Yellow, which conſiſts in Vibrations of Rays a little weakened, but without mixture of Shade, or little mixed with ineffectual Rays. The Rays reflected by the inferior part of the Arc, being more broken, ſince they make a ſmaller Angle, are weaker. By the ſame principle, they are more mixt with ineffectual Rays, and ſo much the more mixt with Shade, becauſe they are found in the extremity of effectual Rays. Hence, the Blue, which conſiſts in very weak Vibrations of Rays ſtrongly mixt with Shade *.

Wherefore, as we have already ſaid, when our Backs are turned toward the Sun, we ſee a kind of Rain-bow upon drops of Water, which the Mouth or Water-ſpouts ſquirt out; and if you place three ſmall Balls of Glaſs full of Water, ſo that one be in the middle, the other below, and the third above, making with the Axis of Viſion Angles of 41 degrees 14′, 41 degrees 30′, and 41 degrees 46′; or if you place the Eye ſucceſſively below the ſame Ball, ſo that the viſual Rays make thoſe different Angles, you ſee the Colours of the Iris in their uſual ſituation.

Ariſt. But the queſtion is, *Eudoxus*, to diſcover the ſecret paths of the effectual Rays in the drops of Water.

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* For the true Cauſe of the Colours in the Rain-bow, ſee Converſat. XXII. Vol. II.

Eudox. 1. The Rays of the Sun enter into the drops of Rain by the upper part. For if one cover the upper part of the ſmall glaſs Balls full of Water, which repreſent the colours of the Iris, thoſe Balls loſe their Colours. 2. The Rays, the moment they enter the Drops, are broken more or leſs in proportion to the inclination with which they fall upon the Drops, and approaching the perpendicular, (*a*) Fig. 4. becauſe they paſs from a more difficult Medium into an eaſier one; namely, from Air into Water. 3. After they have entered, they proceed toward the oppoſite part, following the direction which they received in refraction. Many of them finding there a free paſſage in the Pores of the ſurface, go off, and are ineffectual. Many of them, which encounter ſolid Particles (*b c d*), are reflected downward, making an Angle of Reflection equal to the Angle of Incidence. 4. Thoſe Rays being reflected, at leaſt many of them, come forth by the inferior part (*e f g*) removing from the Perpendicular (*i*), becauſe they paſs from an eaſier Medium into a more difficult one; namely, from Water into Air. 5. This diverging greater or leſs brings to us the effectual Rays, once reflected, and twice broken; and the difference of their Vibrations, more or leſs accompanied with Shadow, forms the different Colours of the Rain-bow.

Ariſt. But why are the Rays ineffectual, which do not make with the Axis of Viſion ſuch Angles as we have ſpoken of?

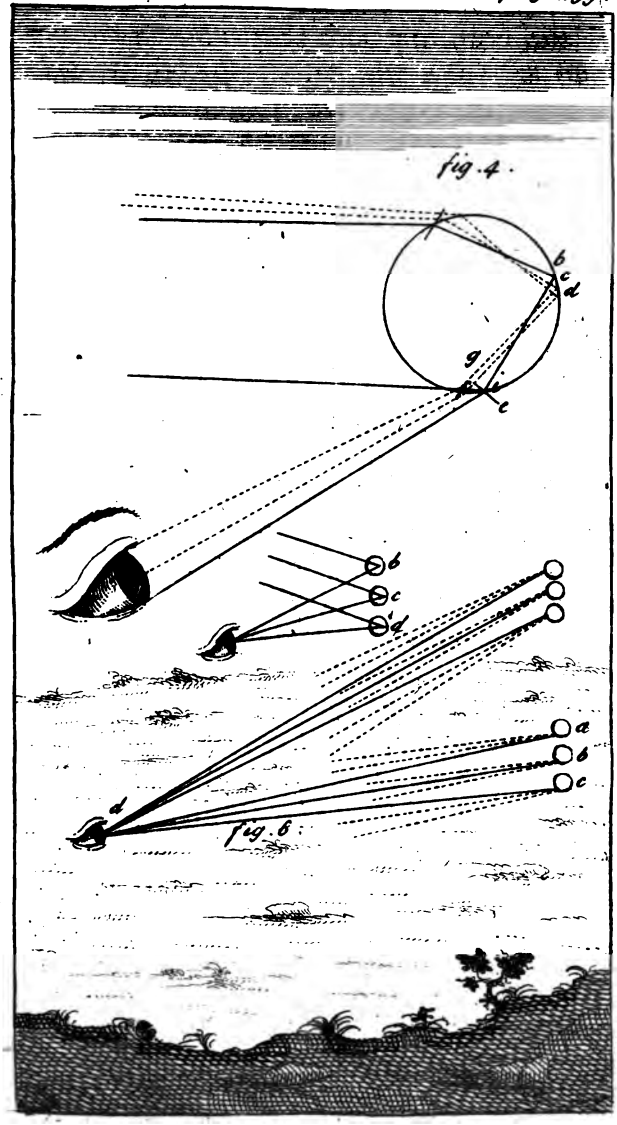


fig. 4.
f
b
c
d
g
f
e
e
b
c
d
a
b
c
d
fig. 6.

Eudox. Becauſe their direction carries them above or elſe below the Eye; as one may ſee in Fig. 6. (*a b c d*) where the Rays (*ad*, *bd*, *cd*) alone are effectual, becauſe the other Rays do not terminate in (*d*), where the Eye is placed.

Ariſt. Hence, one immediately comprehends why the Iris has the figure of an Arc of different Colours. As all Rays of the ſame colour are almoſt equally diſtant from the Axis of Viſion, they ought to be diſpoſed in form of an Arc round about it; the red, yellow, and blue Rays make together a ſort of Cone compoſed of ſeveral Surfaces diverſely coloured. The ſuperior Surface is red, the inferior blue, and that of the middle yellow. The Baſis of the Cone is in the Cloud, which falls down into rain, and the point of it is in the Eye of the Spectator.

Eudox. Thus, two Men do not properly ſee the ſame Rain-bow; becauſe they cannot have their Eyes at the ſame time at the point of the ſame Cone. The Cone differently coloured appears curtail'd. One does not ſee the Circle intire upon the Clouds.

Ariſt. One cannot ſee the Circle intire, unleſs ſome of the viſual Rays come below the Axis of Viſion, which make with the Axis Angles of about 41 degrees. Now none of them come. In order to that, it would be neceſſary, that the extremity of the Axis, which is in the center of the Arc, were elevated about 41 degrees above the Horizon, and conſequently that the other extremity, which is in the Center of the Sun, were as much below the Horizon. But if the Sun is below the Horizon, how can the Axis paſs, as it ought, thro' the Eye of the Spectator?

If the Spectator were plac'd in a part elevated after ſuch a manner, that he ſaw in the Center of the Sun the extremity of the Axis, which is in it, and the other extremity elevated 41 degrees above the Horizon, he would ſee the whole Circle.

Eudox. When the Arc is Weſtward, it diminiſhes continually; but when it is Eaſtward, it increaſes continually.

Ariſt. When the Arc is Weſtward, the Sun is elevated above the Horizon toward the Eaſt; the Extremity of the Axis, which is in the center of the Sun, aſcends at the ſame time, and the other extremity deſcends; and conſequently the Arc diminiſhes proportionally. By a contrary reaſon, when the Arc is Weſtward, it increaſes continually.

Eudox. By the ſame principle, the Northern Rain-bow appears ſometimes in Winter, when the Sun is in the Meridian, but never in Summer. Becauſe in Winter the Sun not being always at the height of 42 degrees in the Meridian, the other extremity of the Axis is not ſo far ſunk below the Horizon, but that one can ſee ſome Segments of the Arc. But in Summer the Sun being elevated more than

42, 50, and ſometimes 60 degrees, the other extremity of the Axis ought to be more than 42, 50, or 60 degrees below the Horizon; and conſequently there are no effectual viſual Rays to make Angles of 41 degrees with the Axis of Viſion.

Ariſt. When the Rain-bow appears, in vain do you attempt to come up to it, it ſeems always to fly before you. Do you fly from it? You would ſay that it affected to follow your Steps. One never finds one's ſelf in a Rainbow, which one ſees.

Eudox. Becauſe it is always changing; when one goes forward or backward, new Rays that come from different Drops of Water ſtrike the Eyes under the ſame Angles, and the Arc only appears at the Extremity of the viſual Rays, which, with the Axis, make Angles of about 41 Degrees. If we were in the middle of the Arc, and ſaw it at the ſame time, we ſhould ſee it when the viſual Rays made, with the Axis of Viſion, Angles of 90 Degrees.

Ariſt. Sometimes the Arc appears interrupted.

Eudox. Becauſe the Cloud it ſelf is interrupted, and there are ſome places which do not remit the Rays to our Eyes, or becauſe the Interpoſition of ſome Cloud hinders the direct Rays from being broken and reflected in the Cloud oppoſite to the Sun.

Ariſt. The Buſineſs is now, *Eudoxus*, to explain what there is that is ſingular in the external Rain-bow.

Eudox. 1. In order to form this Arc, the Rays enter by the inferiour part of the Drops; for in Glaſs-balls full of Water, ſituated after ſuch a manner as to repreſent the Colours of this Arc, and their arrangement, if one hinder the Rays from entering thro' the inferior part, the Balls are not coloured.

2. The Order of the Colours appears turned topſy-turvy in this Arc; becauſe the Rays (*a b c*), which the Drops receive, are received into it, and come out of it by a contrary order, Fig. 5.

3. Why are the Colours of it weaker? Becauſe the Rays admitted below are weakened, not only three times as in the internal Arc, but four times, ſince they are reflected twice in every Drop, and twice broken.

4. The external Rain-bow appears farther diſtant, becauſe it is weaker.

Finally, Sometimes we ſee two Rain-bows, at others only one appears. We ſee two, when at the ſame time drops of Rain fall both from the ſuperiour and inferiour part of the Cloud; ſo that the viſual Rays, which terminate in thoſe Drops, make Angles of 41 Degrees, and Angles of 52 Degrees, or thereabouts. And but one appears, when the Drops only fall from the inferiour part of the Cloud, or when the Rays of the external Arc are too feeble.

Ariſt.

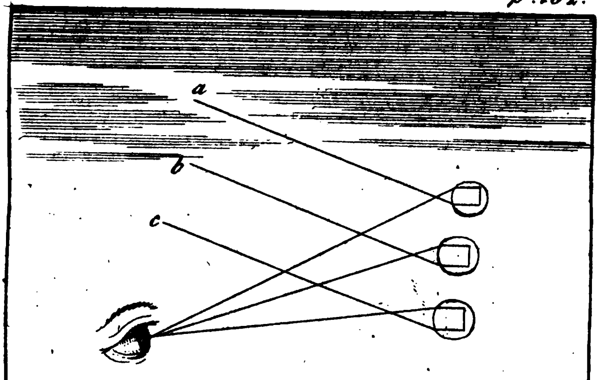
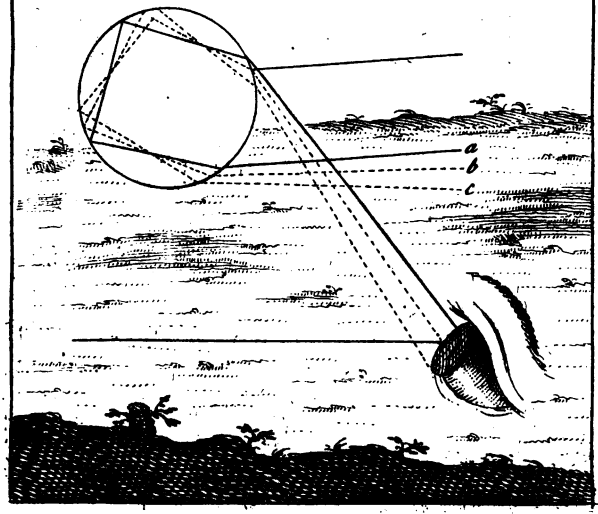


fig. 5.



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UNIV. OF M..H.

Ariſt. After all, *Eudoxus*, a certain Perſon related to me a very rare Phænomenon, which at firſt appears ſomewhat difficult to be reconciled with your Sentiment. One day, when the Sun was elevated about 15 Degrees Eaſtward, and the Weather was the moſt ſerene that could be, ſo that the leaſt Cloud did not appear; Father *Pardis*, who travelled on horſeback, and paſſed over a ſtony Cauſey, conſiderably high, with aſtoniſhment perceived a Rain-bow turned topſy-turvy upon the Graſs of the Meadow. The Colours of it were the brighteſt that can be ſeen. Here is at once a Rainbow turned upſide-down, without Cloud or Rain *.

Eudox. Yow know the Fact; know you its Circumſtances? The Graſs of the Meadow was charged with ſmall Drops of Water, which a thick Miſt had left behind. Theſe ſmall drops of Dew remitting the broken Rays, like drops of Rain, made the ſame Colours appear; and as it was only the loweſt part of the Conic Surface of the coloured Rays, which encountered the drops of Dew, it was that part only which repreſented in the Rain-bow turned topſy-turvy one of the fineſt Phænomena that ever was ſeen.

As for the large Crowns which appear ſometimes round about the Sun or Moon, with ſome of the Colours of the *Iris*; they are probably Rays broken in a frozen Cloud; and of a lenticular figure. In ſhort, the Rays which penetrate Glaſſes made in form of a Lens, paſs thro' and paint beyond thoſe Glaſſes a Crown with different Colours, pretty like thoſe of the Rain-bow.

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* Journ. des Sçav. 7 Fev. 1667. p. 45.

Ariſt. But what do you think of the Parhelia?

Eudox. Theſe are Images of the Sun; which appear ſometimes near the Sun, environed with Colours much like thoſe of the Rainbow. Theſe falſe Suns are cauſed by the Reflexion and Refraction of Rays. Do the Rays fall in a Cloud upon a Plane formed of ſmall pieces of Ice, and equally inclined toward the Sun, and toward our Eyes? They are reflected to us with an Angle of Reflection equal to the Angle of Incidence, and make us ſee the Image of the Sun upon the Cloud, much after the ſame manner as they often repreſent it upon a Plane of Glaſs, or upon the Surface of Water. A great number of Rays broken in ſmall pieces of Ice, having the figure of triangular Priſms, may produce the Colours wherewith the Parhelia are accompanied. And now, *Ariſtus*, when you deſire it, we will carry our Views above the Clouds, and attempt to diſcover what paſſes in the Heavens and Luminaries themſelves.

CONVERSATION XI.

Upon the PLANETS *in general, and the* MOON *in particular.*

Eud. WHAT a pleaſure there is in taking the Air with a Friend in ſuch fair Weather? Is not a Night like this worth the fineſt Day to a Philoſopher? Let us elevate our Views, *Ariſtus.* Is there any Spectacle ſo magnificent? I think I ſee traces of the Wiſdom and Power of the Creator ſhine on all ſides in this vaſt Liquid, in this bluiſh and immenſe Space. Thoſe Luminaries, that Creſcent, thoſe Planets, thoſe Stars, thoſe regular and conſtant Motions; all theſe afford Admiration to any one who knows how to reflect upon what affects the Senſes.

Ariſt. Are you well perſuaded, ***Eudoxus,*** that thoſe immenſe Spaces, in which the Luminaries roll over our heads, are a real Liquid? I have ſeen learned Perſons, who ſeemed to doubt it.

Eudox. How ſhould the Luminaries make the Light glance in our Eyes, with conveying or reflecting luminous Rays from all parts? But the Sun, Stars, and Planets, cannot convey or reflect luminous Rays from all parts, unleſs the immenſe Spaces, which encloſe them, be a real Fluid; the Rays of Light are a liquid and real Matter, as we have obſerved in ſpeaking of Light *: therefore thoſe Spaces are a real Fluid †.

In ſhort, if the Planets, which we ſee turn round about the Earth, are not carried in a Liquid, which retains them in its boſom, why do they not inceſſantly remove farther off? Bodies moved round inceſſantly make an effort, in order to remove from the Center of their Motion.

Ariſt. But, *Eudoxus*, among ſo many ſhining Luminaries, how do you diſtinguiſh the Stars from the Planets?

Eudox. In a ſerene Seaſon, the Stars commonly ſparkle, and the Planets do not, or but rarely. Moreover, Stars always appear in the ſame ſituation with reſpect to one another; and for this reaſon they are ſaid to be fix'd. On the contrary, Planets are ſometimes nearer, ſometimes farther diſtant from one another. You would ſay they wander'd in the Zodiack, and for this reaſon we have given them the name of Planets. By theſe marks it is eaſy to diſcern them, when one has obſerved them for ſome time.

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* Vol. II. Converſ. 16.

† See Notes Converſat. 5. Vol. I.

Ariſt. If I was an *Icarus* or a *Phaëton*, my curioſity would quickly carry me into thoſe Planets, that I might take a nearer view of what paſſes in them.

Eudox. You may know it without running ſo many hazards. The Aid of Teleſcopes alone diſcovers that to modern Aſtronomers, and makes the fartheſt diſtant Objects, as it were, preſent to us. Oftentimes alſo are they informed of Changes that happen twenty or thirty millions of Leagues diſtant from hence, while they are ignorant of what paſſes at *Paris*.

Ariſt. Well, *Eudoxus*, be pleas'd to impart to me what you have remarked in your Obſervations as moſt certain, moſt intelligible, and moſt curious concerning the Planets, as well in general as in particular, as if I had never ſtudied any thing relating to them.

Eudox. They call the Heaven that liquid, immenſe, and blue Expanſion, beſpangled with a prodigious number of Bodies, which we ſee ſhine in it. Theſe ſhining Bodies are the Luminaries. The Planets are ſo many Luminaries. They reckon 16 Planets, ſeven great ones, and nine ſmall, which they call Satellites. The firſt are the *Moon*, the *Sun* in the ordinary Syſtem of the World[f], or the *Earth* in the Syſtem of *Copernicus*[g], of which we ſhall ſpeak hereafter; *Mercury*, *Venus*, *Mars*,

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[f] Vol. I. Converſation 13. Fig. 15.

[g] Ibid. Fig. 16.

Jupiter, and *Saturn*. The other are Species of little Moons, four of which inceſſantly move about *Jupiter*, and five round *Saturn*.

The Planets (I don't ſpeak here of the Sun) are opaque and ſolid Bodies. For their interpoſition with-holds from us the Light of the ſuperior Luminaries, and only reflect a borrowed Light; ſince they have their different Phaſes, that is, divers parts enlightened, or without light, in proportion as they change ſituation with regard to the Sun and Earth.

The ſimple Sight diſcovers in the Planets two Motions, one diurnal and common, from Eaſt to Weſt, thro' Circles parallel to the Equator; and the other from Weſt to Eaſt, but cutting the Equator, according to the Order of the Signs of the Zodiack.

The Planets have their Revolutions, or Returns to the Point whence they proceeded. They have their common and diurnal Revolutions, and their proper Revolutions. The firſt are made ſenſibly every day, from the Eaſt towards the Weſt. The ſecond are made from the Weſt toward the Eaſt, in very unequal times. The Moon accompliſhes her proper Revolution in twenty ſeven Days and eight Hours, or thereabouts; *Mercury* in three Months; *Venus* in ſeven and an half; the *Sun* in a Year; *Mars* in two; *Jupiter* in twelve; and *Saturn* in thirty.

While the Planets make their Revolutions, they are ſometimes nearer, and ſometimes farther diſtant from the Earth. For they appear a ſhorter time, and much larger in certain parts of their Circle, than in others; and the apparent bigneſs of Objects anſwers to their diſtance *. The Point where Planets are fartheſt diſtant from the Earth, is their *Apogee.* The Point where the Planets are leaſt diſtant from the Earth, is their *Perigee.*

As Planets have their Apogea and Perigea, they have alſo their *Aphelia* and *Perihelia.* The Perihelia of Planets is their greateſt proximity to the Sun, and their Aphelia is their greateſt diſtance from it.

Whether the Planets be in their Perigee, Apogee, or middle Diſtance, they are nearer us than the Stars, ſince they with-hold the Stars now and then from our ſight.

Hence Planets have their Conjunctions, Oppoſitions, and Quadratures. They are in Conjunction, when they are under the ſame celeſtial Sign, and in a Line drawn from the Eye to that Sign. They are in Oppoſition when they are in Signs directly oppoſite, or 180 Degrees diſtant. They are in Quadratures, when their reciprocal diſtance is three Signs, or 90 Degrees.

This being granted; let us call to mind the appearances of every Planet in particular, and begin with the Moon: this is the Planet leaſt diſtant from the Earth.

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* 20 Converſ. Vol. II.

Ariſt. By what mark do you know, *Eudoxus*, that the Moon is neareſt us?

Eudox. Becauſe ſhe obſcures the other Planets from our ſight[h]. They obſerved two Eclipſes by the Moon in 1715, the one of *Venus*, and the other of *Jupiter*[i]: One of *Mars* in 1726[k], the 18th of *January*; and one of *Saturn* in 1482, the 12th of *January*[l].

Ariſt. Well, let us begin with the Moon, and in the firſt place give me a Deſcription of her upon the Report of Teleſcopes, Aſtronomers, and your own Eyes.

Eudox. 1. One cannot doubt but that the Moon is an opaque and ſolid Body. For not only are the ſame parts of the Moon ſometimes enlightened, and ſometimes obſcure; but when ſhe happens to be directly between the Sun and our Eyes, ſhe deprives us of the Light of the Sun, ſhe loſes her own, and is cover'd with darkneſs, when the Earth is between her and the Sun.

2. The Moon is a ſpherical Body. Being looked upon with or without Glaſſes, it preſents us with a Figure ſenſibly round. And why do we ſee it in the form of a Creſcent? Becauſe the part illuminated, which ſtrikes our Senſes, is an Arc of a Circle. A Plane, which obliquely receives the Light, does not give it this Figure.

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[h] Kepler. Aſtron. Par. Optica, p. 306, 409.

[i] Hiſt. de l'Acad. 1715. p. 54.

[k] Mem. de l'Acad. 1726. p. 260.

[l] Kepler. Aſtron. Par. Optica, p. 306, 409.

3. In the obſcure part of the Moon, they diſcover Species of luminous Points [m]. Are they not Heights, little Hills, Rocks, and Mountains? According to the Obſervations of *Kepler*, Father *Riccioli*, and Mr. *de la Hire* [n], the Moon is a very rugged Country, covered with an infinity of Mountains higher than ours. And M. *Caſſini* ſays, that he ſaw a Mountain in the Moon, whoſe height ſeemed to exceed three Leagues [o], tho' there are none known upon Earth, whoſe perpendicular height is one League. With Teleſcopes they diſcern the Shadow of thoſe Lunary Mountains, and obſerve it to change according to the different Aſpects of the Sun [p]. Between thoſe Mountains are Cavities, Pits, or very deep Caverns, hollow in a thouſand and a thouſand places. The Light being reflected by the Sides of the Mountains, makes us diſcern them. On the contrary, the Cavities that abſorb the Light which they receive, make in ſome meaſure thoſe obſcure Spots which we ſee upon the Globe of the Moon. I ſay in ſome meaſure; for there are places, which without being Cavities are obſcure. They are probably large Countries, the Land of which is naturally blacker, or more proper

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[m] Taquet. l. 8. Aſtron. Tract. 3. n. 5.

[n] Kepler *in Diſſ. cum nuntio ſidereo.* Riceioli {Alm. T. 1. l. 4. p. 208. Mem. de l'Acad. 1716. p. 110.

[o] Mem. de l'Acad. 1724. p. 405. Hiſt. p. 88.

[p] Taquet. l. 8. Aſtron. Tract. 3. N. 5.

for abſorbing the luminous Rays in its Pores, much after the ſame manner as Coal.

Ariſt. Should not thoſe obſcure large Countries rather be Seas?

Eudox. In thoſe Countries they obſerve Cavities; which is what does not agree to Liquids, as Seas. But would you believe it, *Ariſtus?* From the Quadratures or Quarters to the Oppoſition of the Moon with the Sun, a great number of Cavities and Mountains ceaſe to be diſcern'd; and of obſcure parts become luminous.

Ariſt. I ſee very probable Reaſons for that. 1. Thoſe Mountains being enlightened on the ſide in the Quadratures, their Eminencies become ſufficiently perceptible to our Eyes, by reaſon of the multitude of reflected Rays: but in the Oppoſition, neither the Points nor Eminencies of thoſe Mountains are ſenſible enough, becauſe the Mountains being enlightened in the Front, do not direct Rays enough toward our Eyes. The jutting out of the Figures in Baſſo-Relievo, placed at a moderate diſtance, is more eaſily ſeen when the light ſhines on the ſide of it. 2. Many hollow places, which appear black in the Quadratures, only then receiving oblique Rays, may naturally become luminous and brillant in the Oppoſition; becauſe then being ſeen fully by the Sun, they are Species of large concave Mirrours, whoſe internal, ſolid and rugged Surface, remits the Rays of Light livelily and on all ſides.

But if the Cavities of the Moon have their internal Surface, ſolid and without Water, the Moon ought then to have no Atmoſphere.

Eudox. Accordingly ſhe has none, at leaſt ſenſible. If the Moon had a ſenſible Atmoſphere, we ſhould perceive ſome change in a fix'd Star, or Planet, that approach'd too near to the Diſcus of the Moon, and viſibly touched it. The paſſage of the Rays thro' this Atmoſphere, and their Refraction, would change the Situation, Splendour or Colour of the Stars. Now, the moſt attentive Obſervators of thoſe kind of Changes have remarked none of them in this Caſe. The Moon eclipſed *Venus* the 28th of *June* 1725 *. Meſſ. de *Malezieu*, *Caſſini*, and *Maraldi* obſerved, each with a different Glaſs, and very attentive to the Circumſtance under Conſideration; and, neither in the Immerſion nor Emerſion, that is, when *Venus* was upon the Point of being concealed by the Moon; or when it began to appear again, did they ſee any change, either in its Motion or Figure, or Colour. They perceived nothing of it, no more than M. *de la Hire* did in the time of other Eclipſes of the Planets by the Moon, whether by Day or Night.

It is true, that ſome skilful Obſervers [f] ſaw *Venus* in the ſame Eclipſe ſuddenly change colour upon Immerſion and Emerſion [g]. But ought not this change to be referred to the Perſpective Glaſſes. Thoſe Glaſſes ſometimes diffuſe Colours over Objects, and the ſame Colours over divers Objects [h]. Eſpecially, when the hole of the Objective is large, they make the Colours appear toward the Edges of the Perſpective, and not toward the Centre; the Edges of the Objective being as it were a Circular Priſm, which affords the ſame Colours as a Triangular one. In ſhort, make a fix'd Star enter into a Perſpective: the brim of the Star which is toward the Axis of the Perſpective, becomes red, and the other blue; but the red and blue are defaced when the Star is upon the Axis, or in the Center of the Teleſcope [i]. Thus, leſs than a Month after, the 25th of *July*, Meſſ. *de la Hire*, *Caſſini*, *Maraldi*, *de Louville*, and *de Liſle*, obſerv'd an Eclipſe of *Jupiter* and it's Satellites, by the Moon, without ſeeing in it any change, whether of Figure or Colour, when it was in the Center of the Teleſcope, and in a Situation where its Rays would have been naturally broken by the Atmoſphere [k]. Finally, the 21ſt of *April* 1720, M. *Caſſini* ſaw the Moon eclipſe two fixed Stars, without changing them the leaſt in the world, either as to

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* Mem. de l'Acad. 1715. p. 132.

[f] M. Le Chevalier de Louville, & M. de Liſle.

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[g] M. de l'Acad. 1715. p. 135.

[h] Le P. Dechales, T. 3. Aſtr. l. 3. p. 364. Prop. 2.

[i] Hiſt. de l'Acad. 1715. p. 56.

[k] Mem. de l'Acad. 1715. p. 148, 151, 155, 159. Hiſt. p. 58.

Diſtance, Figure, or Colour [l]. Therefore, the Moon has no Atmoſphere, at leaſt no ſenſible one.

Ariſt. But, when it is fair Weather, and the Moon is in her Decreaſe, or, in her Encreaſe, as at preſent, why do we ſtill ſee this Luminary's Body, at leaſt confuſedly?

Eudox. Becauſe the Rays of the Sun being reflected by the Earth toward the obſcure part of the Moon, make it appear at leaſt confuſedly, as the Rays of the Sun, reflected by the Moon upon the Surface of the Earth, would make it ſeen by Eyes which looked upon it from the Moon. Accordingly this ſecond Light of the Moon is much more lively, when the Moon is ſtill near the Sun, than when ſhe is in her Quarters [m]; becauſe, when ſhe is near the Sun, the obſcure Part receives the Light reflected by the whole Surface of the Earth, which is wholly oppoſite to her, and which is all enlightened with reſpect to her. But when the Moon is in her Quarters, where her Diſtance from the Sun is 90 Degrees, there is only the half of this Surface enlightened, which can diffuſe its reflected Light upon the obſcure Part of the Moon, and theſe Rays being more oblique, are reflected in ſmaller number to our Eyes. Hence, when the Moon is in her Decreaſe [a], and approaches to her Conjunction, this reflected Light is ſtronger, becauſe it proceeds from Eaſtern Countries, where there are fewer Seas. In the firſt Phaſes after the new Moon this Light is weaker, becauſe it proceeds from Weſtern Countries, where there are more Seas. The Land remits more light than Water.

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[l] Mem. de l'Acad. 1720. p. 141.

[m] Taquet. Aſtronom. l. 8. Tract. 3. n. 3, 4. Dechales, T. 3. p. 367.

Ariſt. We may eaſily comprehend why the Moon is ſometimes New, ſometimes Full, in her Encreaſe, or in her Decreaſe; Fig. 7. The Moon (*a*) is new in her Conjunctions, or when ſhe is between the Sun (*b*) and the Earth (*c*); becauſe then the illuminated Hemiſphere of the Moon faces the Sun in ſuch a manner, that it is no wiſe turned towards us, or ſcarcely preſents to our Senſes a luminous Arc. The Moon (*d*) is full in her Oppoſitions, or when the Earth is between her and the Sun; becauſe then the illuminated Hemiſphere of the Moon faces us at the ſame time that it is turned towards the Sun. Laſtly, in proportion as the Moon removes from, or approaches to the Sun; ſhe is in her Encreaſe (*d*), in the Quadratures or Quarters (*e f*) and in her Decreaſe (*g*), becauſe ſhe offers to our Eyes more or leſs of her illuminated Hemiſphere. But how many Motions do you diſtinguiſh in the Moon?

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[a] Suchij è S. I. Optica Philoſophia, p. 252. Taquet. l. 8. Tract. 3. n. 3. S. 4.

r. m p. 176. 177.

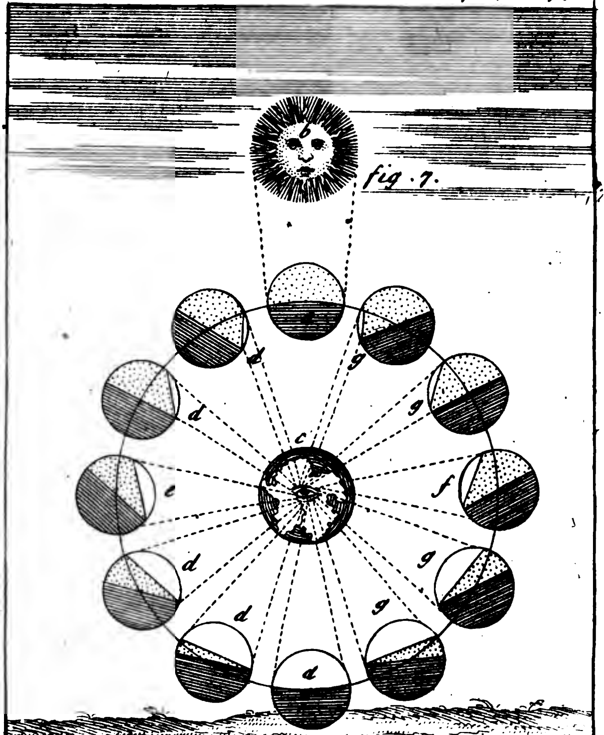

fig. 7.

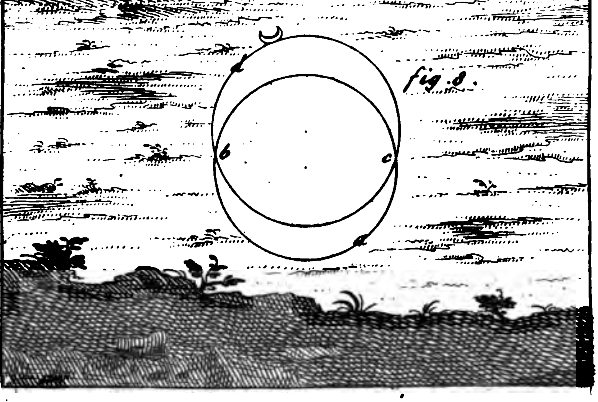

fig. 8.

UNI C M

Eudox. Three, at leaſt; two, whereof we have ſpoken already, namely one common and ſenſible from *Eaſt* to *Weſt*, and the other proper from *Weſt* to *Eaſt*; and a third, upon her Center. The Moon (*d*) accompliſhes her Revolution from Weſt to Eaſt in twenty ſeven Days and eight Hours, or thereabouts, making Angles of about five Degrees with the Ecliptick (*a*) Fig. 8. which it cuts in two Points (*b c*) *. But ſhe is not found to be in conjunction with the Sun, till after twenty nine Days and an half, or thereabouts; for while it has made its periodical Revolution, or has return'd to the point of the Heavens from which it departed, the Sun has run thro' about 27 Degrees of the Zodiack, from Weſt to Eaſt, ſince he makes almoſt one Degree every Day. And that the Moon may run over thoſe 27 Degrees, be joined with the Sun, and be found in conjunction, more than two Days are required; for ſhe only makes about 13 Degrees in a Day †.

Finally, As M. *Caſſini* has obſerv'd, the Moon ought probably in every one of her Revolutions to make one Revolution upon her Center, ſince ſhe always preſents to us the ſame Spots, and conſequently the ſame Hemiſphere. Deſcribe a Circle always facing the Center of the Circle, and you make an entire Revolution upon your ſelf. This is, as if you made one without coming out of the Center. In ſhort, whether you run over a Circle always facing the Center, or you make an intire tour upon your ſelf, ſtill abiding in the Center; I, who am without the Circle not moving, ſee ſucceſſively, your Face, one Side, your Back, the other Side, then your Face again.

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* Riccioli Almag. nov. T. 1. l. 4. cap. 12. p. 218, 219.

† Riccioli Almag. l. 4. c. 18. p. 238. Hiſt. de l'Acad. 1723. p. 74.

However that be, the Moon has her Changes. They diſcovered in her at *Rome*, the 25th of *Auguſt* 1725, in the preſence of the Cardinal *Polignac*, a new and very conſiderable Light in that part which they call *Plato*, (for in honour of the great Philoſophers they thought fit to give their Names to divers Countries of the Moon.) They ſaw the ſame Light in this Planet the 22d of *September* 1727. It ſeem'd to poſſeſs the 32d Part of the Diameter of this Luminary *.

Ariſt. There is probably ſome ſeparation of Mountains made therein; or ſome Country become more hard and ſolid, has begun to reflect the Rays with more force and vivacity.

Eudox. Are you willing, *Ariſtus*, that we paſs from the Planet moſt acceſſible by the naked Eye, to that which is leaſt ſo, even to the Teleſcope? It is *Mercury*.

Ariſt. To-morrow we will ſpeak of *Mercury*, and other Planets. You have taught me News of a World very far diſtant from us: you will, perhaps, be well pleas'd to learn ſome of this here.

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* Obſervations de la Planete de Venus, par M. Bianchini. Mem. de Trev. 1729. p. 1039, 1040. Juin.

CONVERSATION XII.

Upon Mercury, Venus, Mars, Jupiter, *and* Saturn *.

Ariſt. WELL, ſhall we ſee *Mercury* this Evening?

Eudox. You would ſay that he affects to conceal himſelf from the Eyes of the moſt attentive Aſtronomers, ſo rare a thing is it to perceive him. He

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* Beſides the ſimilitude that there is betwixt the Planets and our Earth with reſpect to the Bodies of them, and the Things contained in them; there is alſo another ſimilitude between them with regard to external things, *viz.* The Phænomena of the celeſtial Motions, and the mutual Aſpects of the Planets obſerved from thence. Which ſubject *Huygens in his Planetary Worlds*, *Book* II. having treated very pleaſantly and very aſtronomically, we will here pick a few things out of him; and will ſuppoſe, that there are ſome rational Creatures in every one of the Planets, capable of obſerving the Motions and Phænomena of the Heavens from thence.

To begin then, ſays he, with the innermoſt and neareſt the Sun; we know that *Mercury* is three times nearer that vaſt Body of Light than we are: whence it follows, that they ſee him three times bigger, and feel him nine times hotter than we do. Such a degree of Heat would be intolerable to us, and ſet on fire all our dried Herbs, our Hay and Straw that we uſe. And yet

> He ſhines more than the other Planets, and appears leſs. Being always near the Sun, he hides himſelf in that very Light which environs him.
>
> *Ariſt.*

yet there is no doubt, but that the Animals there, are made of ſuch a Temper, as to be but moderately warm, and the Plants ſuch as to be able to endure the Heat. The Inhabitants of *Mercury*, 'tis likely, have the ſame Opinion of us as we have of *Saturn*, that we muſt be intolerably cold, and have little or no Light, we are ſo far from the Sun.——The Aſtronomy of thoſe that live in *Mercury*, and the appearance of the Planets to them, oppoſite at certain times to the Sun, may be eaſily conceived by the Scheme of the *Copernican* Syſtem. At the times of theſe Oppoſitions, *Venus* and the Earth muſt needs appear very bright and large to them. For if *Venus* ſhines ſo gloriouſly to us, when ſhe is but like the Moon a little after it is new; ſhe muſt neceſſarily in oppoſition to the Sun, when ſhe is full, be at leaſt ſix or ſeven times larger, and a great deal nearer to the Inhabitants of *Mercury*, and afford them Light ſo ſtrong and bright, that they have no reaſon to complain of their want of a Moon. What the length of their Days are, or whether they have different Seaſons in the Year, is not yet diſcovered,————but his Year is ſcarce the fourth part ſo long as ours.

The Inhabitants of *Venus* have much the ſame face of things as thoſe in *Mercury*, only they never ſee him in oppoſition to the Sun; which is occaſioned, by his never removing above thirty eight Degrees or thereabouts from it. The Sun appears to them larger by half in his Diameter, and about twice as big a Face, as to us, and by conſequence affords them but twice as much Light and Heat, ſo that they are nearer our Temperature than *Mercury*. Their Year is completed in ſeven of our Months and a half. In the Night, our Earth, when it is on the other ſide of the Sun from *Venus*, muſt needs ſeem larger and brighter to *Venus* than ſhe ever does to us.

But *Mars* has ſome parts of him darker than other ſome: by the conſtant returns of which, his Nights and Days have been found to be of about the ſame length with ours. But the Inhabitants have no perceivable difference between Summer and Winter, the Axis of that Planet having very little or no Inclination to his Orbit, as has been diſcovered by the Motion of his Spots. Our Earth muſt appear to them almoſt as *Venus* does to

Ariſt. If we ſhould not ſee him at preſent, I ſhall comfort my ſelf, provided you deſcribe him to me ſuch as he appears, when the attention of Aſtronomers can ſurprize him.

Eudox.

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us, and by the help of a Teleſcope, will be found to have its Wane, Increaſe and Full, like the Moon.———His Light and Heat is twice, and ſometimes thrice leſs than ours, to which I ſuppoſe the Conſtitution of the Inhabitants is anſwerable.

In *Jupiter* the length of their Days are equal only to ten of our Hours; but their Years are equal to twelve of ours, and they enjoy a perpetual Equinox there. The Sun appears to them who are upon it five times leſs in Diameter than it does to us, and conſequently they have but the twenty-fifth part of the Light and Heat that we receive from it. But that Light is not ſo weak, as we may imagine, as is plain by the brightneſs of that Planet in the Night; and alſo from hence, that when the Sun is ſo far eclipſed to us, as that only a twenty-fifth part of his Disk remains uncovered, he is not ſenſibly darkned. But if you have a mind exactly to know the quantity of Light that *Jupiter* enjoys, you may take a Tube of what length you pleaſe, let one End of it be cloſed with a Plate of Braſs, or any ſuch thing, in the middle of which there muſt be a Hole, whoſe breadth muſt have the ſame Proportion to the length of the Tube, as a Chord of ſix Minutes bears to the Radius; that is, about as one is to five hundred and ſeventy. Let the Tube be turned ſo to the Sun, that no Light may fall upon a white Paper placed at the End of it, but what comes thro' the little Hole at the other End of the Tube. The Rays that come thro' this will repreſent the Sun upon the Paper, of the ſame brightneſs that the Inhabitants of *Jupiter* ſee it in a clear Day. And if you remove the Paper, and put your Eye in the ſame place, you will ſee the Sun of the ſame magnitude and brightneſs as you would were you in *Jupiter*. If you make the Hole twice as little in Diameter, there will fall upon the Paper and upon the Eye, the ſame Light as the *Inhabitants of Saturn* have. And although this Light be but a hundredth part of ours, yet you ſee it makes *Saturn* ſhine tolerably bright in a dark Night. Further, they in *Saturn* can ſee but one of the other Planets, and that is *Jupiter*; ſo likewiſe they in *Jupiter* can ſee only *Saturn*, for the reſt are too near the Sun to be ſeen. The fixed Stars, by reaſon of their immenſe diſtance, may be ſeen from *Saturn* and *Jupiter* in the

Eudox. 1. This Planet ſcarcely ever removes from the Sun; it is never diſtant above 28 Degrees[a] or thereabouts. 2. Hence, notwithſtanding the uſe of Teleſcopes invented or improv'd about the beginning of the laſt Age, *Mercury* rarely appears, becauſe he is almoſt always loſt and ſwallowed up as it were in the Light of the Sun. 3. He paſſes before the Sun, and ſometimes eclipſes a very ſmall part of it, inviſible to the naked Eye. You only diſcern upon the Diſcus or Hemiſphere of the Sun, a kind of an obſcure Point: *Gaſſendi* ſaw it there in 1632. *Kepler* had foretold the event. Since this Obſervation, which

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very ſame manner, and in the ſame figures, and diſtinguiſhed with the ſame inequality of Light, as we ſee them. It is not to be doubted but that *Saturn* by his five Moons, and *Jupiter* by his four, have a great Advantage above us with our one Moon. But the moſt ſurprizing Phænomena, muſt neceſſarily be produced by that Ring, which we mentioned ſurrounding him. There is alſo a very great difference between Summer and Winter in *Saturn*, becauſe of the great Inclination of his Axis to the place of his Orb, which is thirty one Degrees, whereas ours is but twenty three Degrees and an half. A Year in *Saturn* is equal to thirty of our Years; but what the length of one Day is, is not yet found out.

Laſtly, The Moon is divided into two Hemiſpheres in ſuch a manner, that they who inhabit one of them, have always a ſight of our Earth, and they who inhabit the other never ſee it at all. They alſo ſee our Earth much larger than the Moon appears to us (and which is very wonderful) hanging always at the ſame height above the Horizon as if it never moved, and turning about its Axis in twenty four hours, and its light encreaſing, full, and decreaſing every Month. The Moon alſo receives from us fifteen times as much light as we from it: The Sun alſo riſes and ſets once in every Month of ours, which makes the Days and Nights very long.

[a] Hiſt. de l'Acad. 1706. p. 106.

paſſes for the firſt [b], they have made five or ſix others of the ſame ſort [c]. One ſuch Obſervation alone is a Conqueſt, a Triumph for an Aſtronomer. 4. It evidently follows from this, that *Mercury* is an opaque Body, and ſhines only with a foreign Light. Accordingly he has his different Phaſes, Fig. 9. according as he is differently ſituated with reſpect to the Sun and Earth.

Sometimes he ſcarcely preſents to our Eyes one ſmall luminous trace (*a*), becauſe being between the Sun (*b*) and the Earth (*c*), he only preſents to us a very ſmall part of his enlightened Hemiſphere. Sometimes he is like a Species of little Moon in its Increaſe (*e*), in his Quarters (*f*), *&c.* becauſe in a middle diſtance he turns toward us a greater part of his luminous Diſcus. Sometimes he is a ſort of full Moon. His luminous Diſcus appears intire, or almoſt intire * ; becauſe being above or beyond the Sun, he preſents to our eyes his whole Hemiſphere, or almoſt his whole Hemiſphere enlightened †. If the Hemiſphere does not appear whole and intire, the Reaſon is probably, becauſe there are ſome inequalities in the Planet, or ſome parts not ſo proper for reflecting Light. 5. If

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[b] They ſay however, that one was made in 807. Kepler. Aſtron. Par. Optica, p. 306.

[c] Hiſt. de l'Acad. 1706. p. 104.

* P. Scheinerus, S. 1. in Diſquiſ. Mathem. N. 38.

† P. Riccioli Almag. Tom. 1. lib. 7. p. 484. Kepler. Epiſt. Aſtron. p. 762.

Mercury were always between the Sun and the Earth, he would ſcarcely preſent to us one ſmall part of his enlightened Hemiſphere. If he were always at the ſame diſtance, on the right or left, he would never appear full. If he were always above the Sun, one ſhould never ſee him in form of a Creſcent. He would always appear round, or almoſt round. He muſt therefore move round about the Sun. *Mercury* can't be ſometimes on this ſide, ſometimes above or beyond, and ſometimes on the ſide of the Sun, without moving round about this Luminary. 6. The Circle which he deſcribes about this Luminary, he accompliſhes in about three Months *. 7. This Circle is excentrick. It is nearer the Sun in ſome of its Points, and farther off in others. Indeed *Mercury*, which runs thro' it, is ſometimes nearer the Sun, and ſometimes more remote. The difference of its greateſt and leaſt diſtance is about ten degrees †.

Mercury has his Perigeon and Apogeon; ſince ſometimes he is on this ſide, and ſometimes beyond the Sun. And what will perhaps ſurprize you, in his Perigeon he appears leſs than in his Apogeon, altho' in his Perigeon he is nearer us.

Ariſt. I apprehend the Reaſon of it. Becauſe in his Perigeon, as he is between the

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* Découverte de la Lumiére Céleſte dans le Zodiaque, p. 26. Receuil d'Obſervations, par Meſſ. de l'Acad.

† Kepler Epiſt. Aſtr. p. 763.

Earth and the Sun, he ſcarcely preſents to our Eyes any part of his enlightened Surface; and in his Apogeon he ſhews us this Surface intire, or almoſt intire, being then above the Sun, which is between the Earth and him.

Eudox. Finally, *Mercury* has more brightneſs than *Venus* herſelf [d], becauſe he is nearer the *Sun*. Nevertheleſs the Appearances of *Venus*, of this ſhining Planet, which is going to deſcend below the Horizon, are more ſenſible. 1. *Venus* moves round the *Sun* as *Mercury*; for like *Mercury*, ſhe is ſometimes below, ſometimes above, ſometimes on the ſide of the *Sun*, and like *Mercury*, ſhe has her different Phaſes [e]. 2. Her diſtance from the *Sun* is not always the ſame. Wherefore her Circle is excentrick [f]. 3. The Circle which ſhe deſcribes, is larger than that of *Mercury*. Accordingly, one ſees her farther diſtant from the *Sun*. Notwithſtanding ſhe never removes farther than about 48 degrees [*]. 4. Her Circle cuts the Ecliptick, and makes with it an Angle of three degrees and an half. 5. There is no doubt but that *Venus* is an opaque and ſolid Body. For ſhe has, much after the ſame manner as *Mercury* and the *Moon*, her different Phaſes [g], according to her different Situations,

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[d] Galilée Dial. 3. de Mundi Syſt. Riccioli Almageſti, T. 1. l. 7. p. 484.

[e] Riccioli Almageſti, T. 1. l. 7. c. 4. p. 495.

[f] Ibid. p. 485.

[*] Kepl. Epiſt. Aſt. p. 763.

[g] Ric. Alm. T. 1. l. 7. p. 495.

tions, with reſpect to the *Earth* and the *Sun*, which affords her light[h]. 6. *Venus* is a very bright Planet by reaſon of her largeneſs, ſolidity, inequalities proper for reflecting Light on all ſides, and nearneſs to the *Sun*. According to the Obſervations of M. *Caſſini*, the Diameter of *Venus* is about 2822 common Leagues; and her Globe almoſt equal to that of the Earth. With a Glaſs of ſixteen Foot, ſhe appears three times bigger than the *Moon* does to the naked Eye[i]. Notwithſtanding her brightneſs, ſhe has her Spots[k], much after the ſame manner as the *Moon*. They have lately obſerved thoſe Spots at *Rome* with a Glaſs of *Campani*, one hundred and fifty Palms long, and made by the Order, and at the Charges of Cardinal *Polignac*. M. *Bianchini* made Obſervations in 1724, 1726, 1727: He made them, I ſay, in 1726 with Cardinal *Polignac*, from the ninth of *February* to the tenth of *March*. And the Spots were diſcovered to their diſcerning Eyes, in as diſtinct a manner as one ſees the Spots of the *Moon* without Glaſſes. There are ſeven principal Spots toward the Equator of the Globe of *Venus*, and two others toward the Poles. M. *Bianchini* concluded from the return of the Spots, that the Revolution of *Venus* upon her own Axis is accompliſhed, not in twenty three hours *, as had been conjectured, but in twenty four days and about eight hours †. M. *de la Hire* obſerved therein ſeveral times, inequalities more conſiderable than thoſe of the *Moon*‡. This Diſpoſition, almoſt frightful, may contribute to render the Planet ſo bright and comely at a diſtance. Nothing reflects Light more lively, at a great diſtance, than a number of Rocks very elevated and dry.

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[h] Ibid. p. 484. M. de l'Ac. 1700. p. 290.

[i] Ibid.

[k] Ric. Alm. T. 1. lib. 7. p. 485. M. de l'Acc. 1700. p. 290. Reç. d' Obſ. du progrés des Aſtr. p. 37.

Mars has much leſs ſplendor than *Venus*; eſpecially when he is not in his Perigeon. Do you ſee that Luminary whoſe Light is reddiſh, and which does not twinkle? It is *Mars*.

Ariſt. Well, what are the Appearances of *Mars?*

Eudox. 1. *Mars* accompliſhes his Orbit in the Heaven in two years, or thereabouts; that is, in a Year and ten Months and a half, making with the Ecliptick an Angle of one Degree fifty Minutes. He contains within his Circle both the *Earth* and the *Sun*, ſince he does not paſs between the *Sun* and the *Earth*. Thus, is he nearer the *Earth* in his Oppoſitions, and farther diſtant in Conjunctions; 2. He has different Phaſes, according to his different ſituation with reſpect to the *Earth* and *Sun*[m]. For he appears full in his Oppoſitions and Conjunctions; becauſe then the whole Hemiſphere preſented to us is illuminated by the *Sun*. But in his Quadratures we only ſee one part of the Hemiſphere that faces us, the other not being enlightened, becauſe it is not turned toward the *Sun*. 3. When *Mars* is in oppoſition with the *Sun*, or when the *Earth* happens to be between the *Sun* and *Mars*, he is in his Perigeon, and when he is in his Perigeon, eſpecially if he is in his Perihelion at the ſame time, he ſeems to be nearer the *Earth* than the *Sun* itſelf[n], and ſo big and luminous, that one would take him for a new Planet[o]. 4. When *Mars*, Fig. 10. is ſo near us, one ſees in him, with Proſpective Glaſſes, Lines or Spots[p], ſome clear, others obſcure. The firſt are parts which remit the Light livelily; the others are places which reflect it but weakly. From the Revolution of thoſe Spots they conclude, that the Planet makes a Revolution upon its Axis[q] in twenty four Hours and forty Seconds[r]. Large Spots are often ſeen to diſappear in it after ſome Years, or ſome Months;

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* Du progrés de l'Aſt. p. 37.

† Obſervations de la Planete de Venus, Mem. de Trev. Juin. 1729. p. 1038, 1039, 1040, 1041.

‡ Mem. de l'Acad. 1700. p. 290.

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[m] Riccioli Almageſti. T. 1. l. 7. p. 496.

[n] Elémens de l'Aſt. p. 34. par. M. Caſſini. Recüeil d'Obſerv.

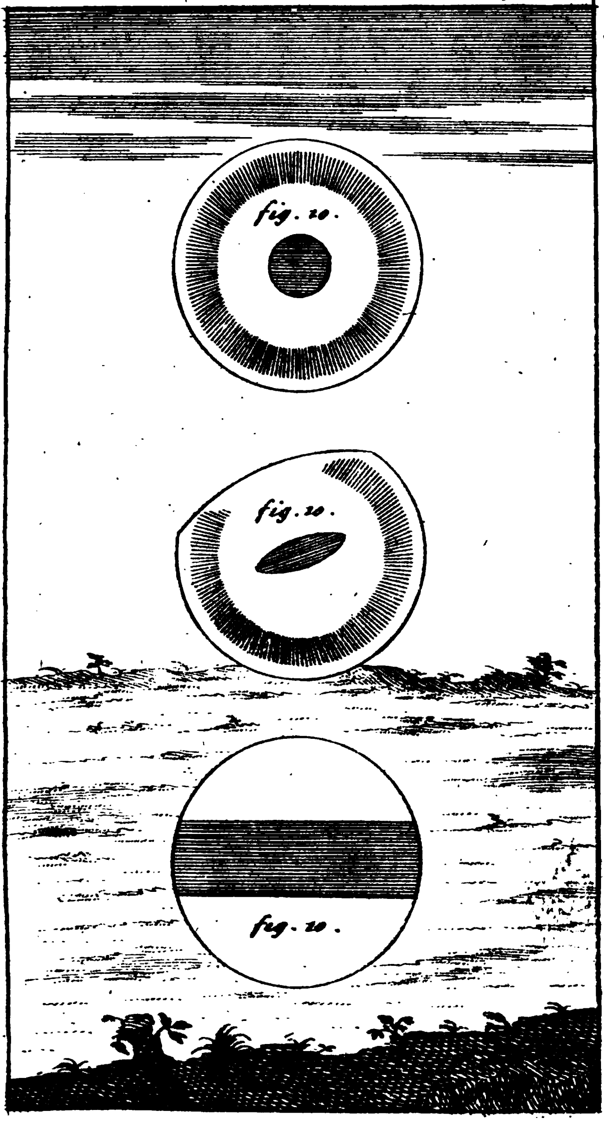
[o] Kep. Aſtr. pars Opt. p. 333. Mem. de l'Acad. 1720. p. 145.

[p] Ricci. Almag. T. 1. l. 7. c. 2. p. 486.

[q] Ricci. Almag. T. 1. l. 7. c. 2. p. 486.

[r] Mem. de l'Acad. 1720. p. 146. Du progrés de l'Aſtron. Recüeil d'Obſerv. par Meſſ. de l'Acad. p. 37.

while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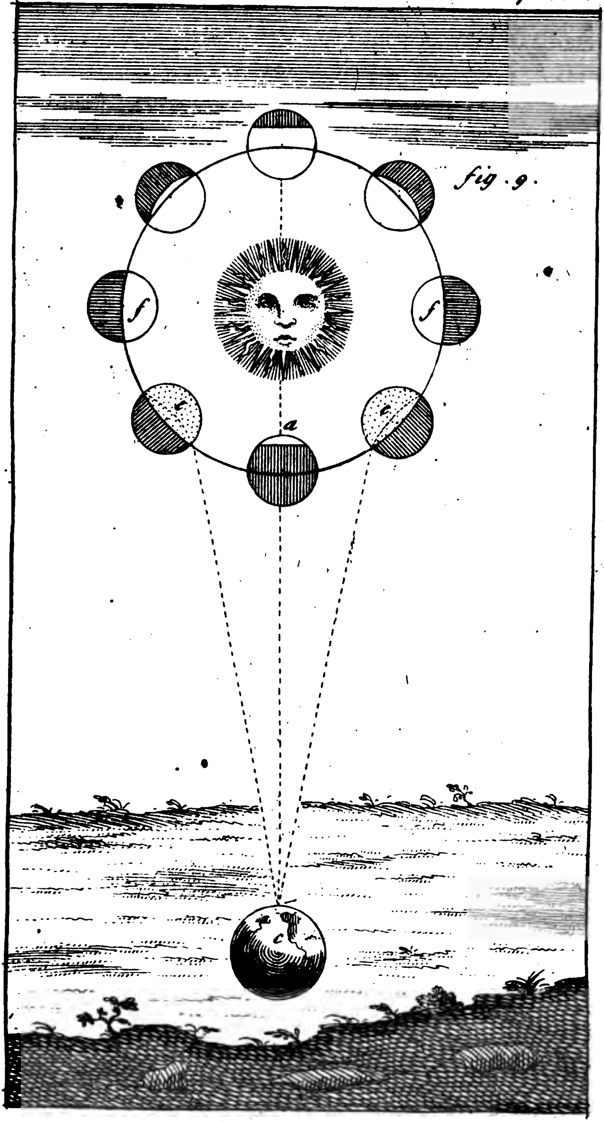

while they ſee others formed and ſubſiſting for ſeveral Months, and ſeveral Years [f].

Ariſt. Therefore ſome ſtrange Changes muſt happen in *Mars*, ſince they are perceptible at ſuch a diſtance; and the Surface of the *Earth* muſt be very quiet in compariſon of that of *Mars*. For ſcarcely has there happened, for the ſpace of 4000 Years, any ſenſible change upon the Surface of our Globe.

Eudox. Our Lands, great Ridges of Mountains and Seas, only preſent us with changes, which would not be perceived from *Mars* with the beſt Glaſſes. Nevertheleſs the *Earth* muſt have had conſiderable Revolutions; for in a word, Trees ſunk to very great depths, and Shells and Skeletons of Fiſhes buried in Lands and Mountains, are ſufficient proofs of it.

Since the *Earth* and *Mars* have their Changes and Spots, it is natural that *Jupiter* has alſo his Spots and Changes. You may ſee, *Ariſtus*, this Luminary in the middle of the Heavens, whoſe Splendor is lively, without twinkling? This is *Jupiter*. Altho' he is larger than *Venus*, he is leſs bright.

Ariſt. The Reaſon of this, no doubt, is becauſe being farther diſtant from the *Sun* and us, than *Venus*, he receives from the *Sun* a fainter Light, and the exceſs of Diſtance weakens it ſtill more in the Reflection which is made of it to our Eyes.

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[f] Mem. de l'Acad. 1720. p. 151, 152, &c.

Eudox. *Jupiter*, Fig. 11. has his different Phaſes, as the other Planets. He has his Spots (*a b*) in form of Belts ſometimes more, ſometimes leſs numerous; ſometimes larger, ſometimes ſmaller [t], by reaſon of the Inequalities of his Surface, parts leſs proper for remitting Light and Changes which happen therein, as in *Mars*, whether by the Action of the Rays of the *Sun*, or by that of the ſubtle Matter which penetrates the Planet. You ſee that thoſe Belts ſhrink after many Years, or are enlarged, or interrupted, and after that united again. Some new ones are formed, and ſome are defaced. Changes more conſiderable, than if the Ocean ſhould overflow the entire firm Land, and leave new Continents in its place. The Spots which are nearer the apparent Center of *Jupiter*, have a quicker Motion than the others, which have a larger Circle to run thro' in the ſame time. They ſee the ſame Spots move from Eaſt to Weſt, diſappear, and then appear again after nine Hours and fifty ſix Minutes [u]. Whence they conclude that *Jupiter* turns round upon his own Axis, and makes a Revolution in ten Hours, ſome Minutes leſs. In this Revolution, the upper part of the Planet moves from the Weſt

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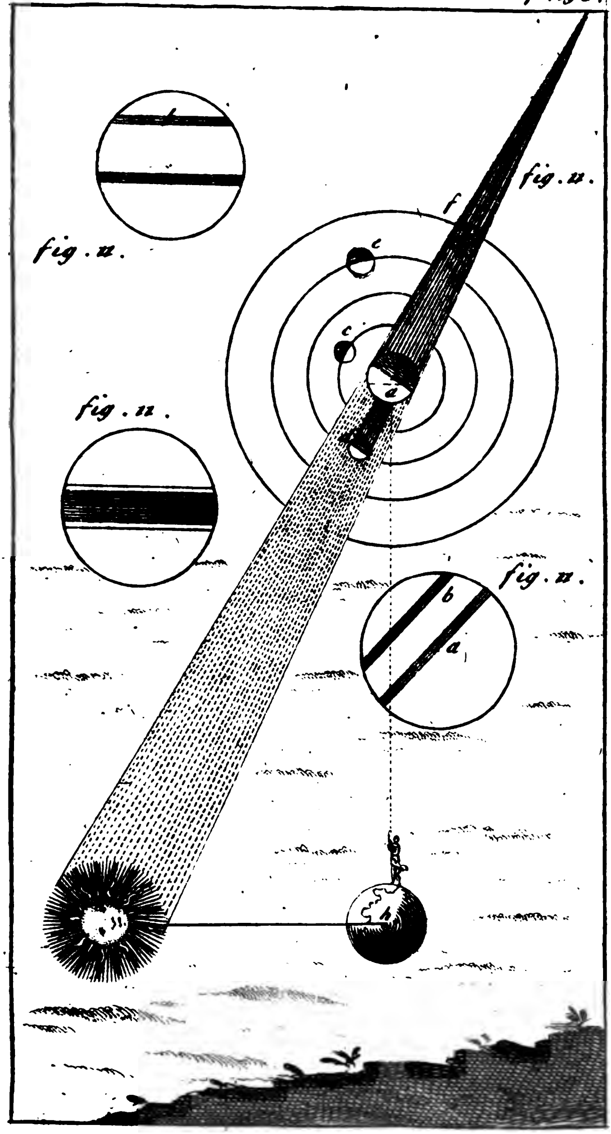
[t] Riccioli Almag. l. 7. c. 2. p. 486.

[u] De l'Origine & du Progrés de l'Aſtronomie Caſſini. Recüeil d'Obſervations, par M M. de l'Academie, p. 36. Découverte de la lumiére céleſte, &c. p. 24. Mem. de l'Acad. 1699. p. 104, 106. Hiſt. p. 78.



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towards the Eaſt, and the inferior Hemiſphere moves from the Eaſt toward the Weſt [x], ſince one ſees the Spots move from the Eaſt toward the Weſt.

This Luminary is ſurrounded with four Species of little Moons. They are its four Satellites, inviſible to the naked Eye. The firſt (*c*), that is to ſay, that which is neareſt to *Jupiter*, makes its Revolution round this Planet in one day, 18 hours, and 22 minutes, or thereabouts. The ſecond (*d*), in 3 days, 3 hours 14′. The third (*e*), in 7 days, 9 hours, 42′; and the fourth (*f*) in 16 days, 3 hours, 2′. When they are in Conjunction with the Sun, they hinder one Cone of Light from reaching the Planet. And there is a Shadow (*g*) which they caſt upon it. This Shadow is a kind of Spot moveable upon *Jupiter*; it is an Eclipſe. And if the Earth (*h*) is not in the ſame Line, we ſee this Eclipſe, or this changing Obſcurity run over the Diſcus of *Jupiter* from Eaſt to Weſt [y]. Sometimes the Satellites appear greater or leſs, without being more or leſs diſtant. The ſhadow of the fourth ſpread upon the principal Planet, appears ſometimes larger than the Satelles itſelf which is the Cauſe of it [z].

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[x] Ric. Alm. T. 1. l. 7. p. 489.

[y] Du progrés de l'Aſtron. par M. Caſſini. Recüeil d'Obſerv. par M M. de l'Acad. p. 38.

[z] Mem. de l'Acad. 1707. p. 295.

Ariſt. Becauſe probably they have their Spots, obſcure parts and places more or leſs proper for reflecting Light. When they turn toward us their more ſolid parts, and more proper for remiting the Light, they appear bigger. The more luminous objects are, the more apparent bigneſs they have, becauſe in that caſe the Impreſſion is more extended upon the Retina [a]. But if the Satellites preſent to us their Spots, or parts capable of abſorbing the Light, they thereby appear the ſmaller, becauſe the reflected Light paints a ſmaller Image upon the Organ of Sight.

Eudox. In fine, *Galilæus*, who firſt diſcovered the Satellites of *Jupiter* with a Teleſcope, in the beginning of the laſt Age, gave them the ſpecious Name of *Medicean Stars* [b].

As for *Saturn*, 1. He has his different Phaſes, as well as *Mars* and *Jupiter*, and changing Belts [c]. 2. He appears ſometimes round (*a*), Fig. 12. Sometimes elliptick (*b*). Sometimes they ſee in him two Species of Ears (*c*, *c*), which appear and diſappear from time to time. Thoſe Ears are like two luminous Arcs of a Circle, and directly oppoſite; which contain, each, an obſcure Segment (*d*, *d*). Theſe obſcure Segments are contain'd

fig. 12.

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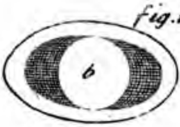
[a] 20 Converſ. T. II. p. 357.

[b] Nuncii Syderei. p. 17, &c. Riccioli Almag. T. I. p. 488, 489.

[c] Hiſt. de l'Acad. 1705. p. 44.



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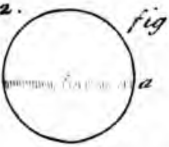

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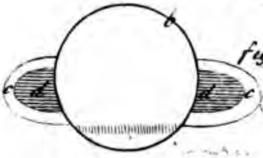

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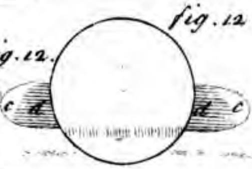

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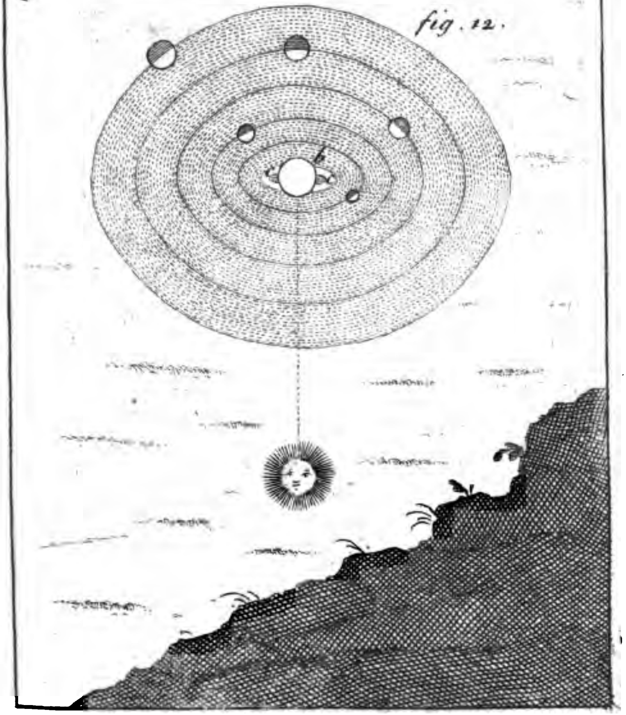

tain'd between the Ears and the Globe of the Planet.

In order to explain theſe Appearances, M. *Huygens* aſcribes to *Saturn*, a Ring (*c c*), whoſe Plane is very large, and the thickneſs very minute, and which ſurrounds the Planet, much after the ſame manner as the Horizon ſurrounds an artificial Globe. The external circumference of the Ring appears elevated more than 18000 Leagues above the Surface of *Saturn*[ſ]. This Ring ſeems to be nothing elſe but a Maſs and Train of Satellites ſo near one another, that they only make an appearance of a continued Ring. The Ring happening to be between the *Sun* and *Saturn*, projects a moveable Shadow over *Saturn*; and this is a Species of Belt.

The ſight of the round Phaſis, of the elliptick Phaſis, or others, depends upon the poſition of the Ring, both with reſpect to the *Sun*, and with reſpect to our Eye.

Does the Plane of the Ring paſs thro' our Eye? We do not ſee it; becauſe the back or edge of the Ring is all that one can ſee of it; and it is too minute to be perceptible at ſo great a diſtance. Wherefore *Saturn*, whoſe Globe is ſpherical, appears alone in his round Phaſis, which is what is obſerved from fifteen Years, to fifteen Years[t].

[ſ] Hiſt. de l'Acad. 1715. p. 45. Mem. p. 46.

[t] La Découverte de la Lumiére Céleſte qui paroît dans le Zodiaque, p. 25. Receuil d'Obſerv. par Meſſ. de l'Acad. des Sciences.

But the Poſition of the Ring changes; the Plane of the Ring is inclined to the viſual Ray, and faces us obliquely at the ſame time it receives the Rays of the *Sun*. One part of the circular Plane is hid behind the Globe, and another part is ſituated before the Globe, to which it appears applied without letting the intermediate Space be ſeen; and confounding its Light with that of the Globe of the Planet, it gives the apparent Diſcus the figure of an Ellipſis.

In ſhort, among Circles of a Sphere ſeen at a certain diſtance, thoſe, whoſe Plane paſſes through our Eye, are ſeen in a direct Line, and the others appear in form of Ellipſes, more or leſs large, according as the viſual Ray, which paſſes from our Eye to the Center of the Circles, is more or leſs elevated above their Plane.

While the inferiour part of the circular Plane of the Ring confounds its Light with that of *Saturn*, one diſcerns two oppoſite Portions of the Ring almoſt equal, which are at the two extremities of one of its Diameters prolonged, and contain two obſcure Segments (*d d*). Thoſe two oppoſite Arches are called the Ears or Handles of *Saturn*, by reaſon of their figure.

Ariſt. The obſcure Segments contained between the Ears and the Globe of the Planet are probably two intervals of etherial Matter, incapable of reflecting the Light, and intercepted between two oppoſite extremities of the Globe of the Planet, and two oppoſite parts of the Ring.

Eudox. Laſtly, if the Ring happen to be ſo plac'd, that its prolonged Plane paſs thro' the center of the Sun, there is nothing but the back of the Lamina or of the Ring which receives the Rays of the Center; and as this Lamina is minute, and its back narrow, it eſcapes our ſight. At the ſame time each Surface of the Plane of the Ring receives Rays but from one half of the Sun, and very obliquely. Wherefore, the Surface, which may face us, remits to us too little Light; and a Light too oblique and too faint to be perceived at ſuch a diſtance. Hence the Ears diſappear. The Light of *Saturn* is feebler than that of other Planets.

Ariſt. I am not ſurprized at that. This Planet is much farther diſtant from the very Source of Light.

Eudox. Notwithſtanding his diſtance, we ſee that he hath five Satellites, by the help of Teleſcopes. M. *Huygens* diſcovered the fourth, counting by their diſtance from the principal Planet, and M. *Caſſini* the other *. The firſt of the Satellites compleats its Revolution in about one Day and 21 Hours; the ſecond, in 2 Days and 17 Hours; the third, in 7 Days and 13 Hours; the fourth, in 15 Days and 22 Hours; and the fifth, in 79 Days and 22 Hours[u]. The fourth was diſcovered in 1655. The fifth in 1671. The third in 1672. The firſt and ſecond in 1684[x]. The Satellites move in their Revolutions round about the principal Planet, and as the primary Planet, from the Weſt toward the Eaſt, in the ſuperiour part of their Circle; and in the inferiour part, from Eaſt to Weſt[y]. The fifth Satellite of *Saturn* augments and diminiſhes in bigneſs without any regard to its diſtance; and in every Revolution it remains a long time hid toward its greateſt digreſſion Eaſtward; altho' the other Satellites are never better ſeen than in their greateſt Digreſſions.

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* Découverte de la Lumiére céleſte dans le Zodiaque. Receuil d'Obſervations, par Meſſ. de l'Acad. p. 21.

Ariſt. Becauſe probably the whole Surface of the fifth Satellite is not equally fit to reflect the Light, and turning upon its own Axis, it preſents to the Earth its leſs luminous Hemiſphere, when it is not viſible; and its moſt lunous Hemiſphere, when it is clearly ſeen.

Eudox. Henceforth, *Ariſtus*, we may turn our Eyes toward the Source itſelf of the Light, and fix them without any danger upon the Sun itſelf.

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[u] Hiſt de l'Acad. 1705. p. 117.
[x] Mem. de l'Acad. 1716. p. 205, 208, 210, 212, 215.
[y] Hiſt. de l'Acad. 1716. p. 57.

Conversation XIII.

Upon the Sun.

Ariſt. At laſt, *Eudoxus*, what is the *Sun*, this ſo wonderful Luminary, whoſe Abſence or Diſtance ſpreads a kind of Horrour over Nature, but whoſe Return animates it again, covering the Earth with Harveſt, Flowers, and Fruits? He unveils to my Eyes whatever ſenſible Objects have in them moſt affecting; and yet, if I may ſo ſay, he remains in darkneſs with reſpect to my Mind.

Eudox. 1. The Sun is a Globe of Fire *, bigger than the Earth, and on all ſides ſurrounded with etherial Matter. It is a Globe, I ſay. It appears like a Diſcus to the naked Eye; but with Teleſcopes we ſee the Convexity of the Hemiſphere which faces us. It

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* Since the ſubtle Matter and Vortices ſo often mentioned have been ſhewn to be entirely fictitious and contrary to the Phænomena of Nature; let us hear what the Illuſtrious Sir *Iſaac Newton* ſays ſo incomparably well concerning the Nature of the Sun and Stars from other Principles. " Do not great " Bodies, *ſays he*, conſerve their Heat the longeſt, their Parts " heating one another; and may not great denſe and fixed Bo- " dies, when heated beyond a certain Degree, emit Light ſo " copiouſly, as by the Emiſſion and Re-action of its Light, and " the Reflections and Refractions of its Rays within its Pores, to " grow ſtill hotter, till it comes to a certain period of Heat, " ſuch as is that of the Sun? And are not the Sun and fixed Stars

" great Earths vehemently hot, whoſe Heat is conſerved by the " greatneſs of the Bodies, and the mutual Action and Re-action " between them and the Light which they emit, and whoſe " Parts are kept from fuming away, not only by their Fixity, " but alſo by the Weight and Denſity of the Atmoſpheres incumbent upon them, and very ſtrongly compreſſing them, and " condenſing the Vapours and Exhalations, which ariſe from " them? For if Water be made lukewarm in any pellucid Veſſel, " and that Veſſel be afterwards emptied of Air, that Water in " the *Vacuum* will bubble and boil as vehemently as it would do " if heated much hotter in a Veſſel ſet on the Fire in the " open Air. For the Weight of the incumbent Atmoſphere " keeps down the Vapours, and hinders the Water from boiling, " until it grow much hotter than is requiſite to make it boil *in* " *vacuo*. Alſo a mixture of Tin and Lead being put upon a " red-hot Iron *in vacuo*, emits a Fume and Flame; but the " ſame mixture in the open Air, by reaſon of the incumbent " Atmoſphere, does not ſo much as emit any Fume, which " can be perceived by ſight. In like manner the great Weight " of the Atmoſphere, which lies upon the Globe of the Sun" (For the Weight of Bodies upon the Superficies of the Sun, is to the Weight of Bodies upon the Superficies of the Earth, as the magnitudes and denſity of the Sun is to the magnitude and denſity of the Earth) " may hinder Bodies there from riſing up " and going away from the Sun in the form of Vapours and " Fumes, unleſs by means of a far greater Heat than that " which on the Surface of our Earth, would very eaſily turn " them into Vapours and Fumes. And the ſame great Weight " may condenſe thoſe Vapours and Exhalations as ſoon as they " ſhall at any time begin to aſcend from the Sun, and make " them preſently fall back again into Him, and by that Action " encreaſe his Heat; much after the manner, that on our " Earth the Air encreaſes the Heat of a culinary Fire. And the " ſame Weight may hinder the Globe of the Sun from being diminiſhed, unleſs perhaps by the emiſſion of Light, and a very " ſmall quantity of Vapours and Exhalations." *Newt. Opticks.* p. 318.

fig. 13.

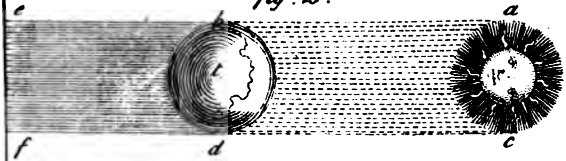


fig. 14.

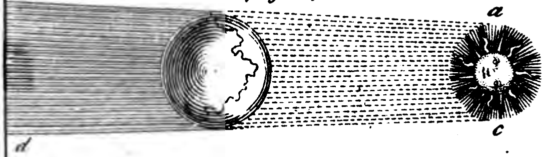
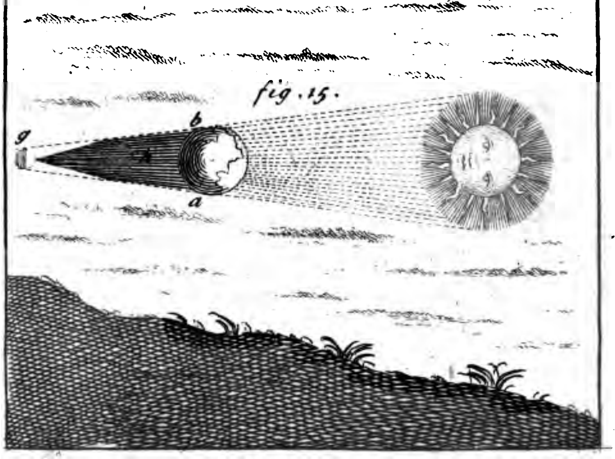


fig. 15.



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is a Globe of Fire; ſince it enlightens, warms, ſparkles and ſhines like terreſtrial Fire. Laſtly, it is a Globe larger than the Earth, if the Shadow which the Earth projects when oppoſite to the Sun proceeds ſtill diminiſhing its Diameter; for if the *Sun* (*s*) Fig. 13. was of the ſame Diameter with the Earth (*t*), the Rays (*a b*, *c d*,) which would glance upon the Earth, would be parallel, and conſequently the Shadow (*e f b d*) contain'd between thoſe Rays would never diminiſh. If it were leſs, the Rays (*a b*, *c d*,) Fig. 14. which grazed upon the Earth would diverge, and the Shadow contained between them would augment in bigneſs. Now the Shadow of the Earth (*a b c*) Fig. 15. ſtill diminiſhes in Diameter; otherwiſe it would be diffuſed upon the ſuperiour Planets (*g*). It would eclipſe them; and it only eclipſes the Moon (*h*). Therefore the *Sun* is a Globe of Fire, larger than the Earth. Thus the moſt skilful Aſtronomers make it much larger upon other Principles *. According to M. *Caſſini*, the Globe of the *Sun* is a million of times bigger than the Earth †. And ſince it ſpreads Light abroad on all ſides, it muſt on all ſides be ſurrounded with etherial Matter.

2. This Globe of celeſtial Fire is probably a collection of ramous and groſs Matter

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* Ricc. Almag. T. 1. p. 294.

† Elém. de l'Aſtron. p. 49. Rec. d'Obſerv. par Meſſ. de l'Acad.

moved rapidly on all ſides by the action of a ſubtile and fine Matter. For it is a Fire which very much reſembles terreſtrial Fire; ſince it enlightens, warms, ſparkles, ſhines, and darts out Rays on all ſides, as the Fire which we kindle upon the Surface of the Earth. Now terreſtrial Fire is a Collection of ramous and groſs Matter, hurried on all ſides by the rapid Motion of ſubtle and fine Matter [*]. Therefore, *&c.*

But ſeeing the *Sun* ſo white, ſo luminous to the naked Eye, would you believe, *Ariſtus*, that it had its Obſcurities and Spots, as *Mars* and *Jupiter* have? There are ſome Years which have not a Month, but what ſome Spots in the *Sun* are obſervable [a]. Father *Scheiner* [b], a Jeſuit, and *Galilæo*, were the firſt who obſerved any.

Ariſt. The brightneſs with which this Planet ſhines, would not make one ſuſpect its being covered with Shades and Obſcurities.

Eudox. I ſaw upon the Diſcus of this Luminary, with a Teleſcope, whoſe Glaſſes were coloured, ſeven or eight heaps of Spots at once. In order to obſerve them, it is ſufficient to receive the Image of the *Sun* into an obſcure Room, thro' a Hole which contains a convex Glaſs in form of a Lens, or a Teleſcope[c]. They have remarked in the *Sun* forty or fifty Spots at the ſame time. Sometimes you would ſay that it is ſurrounded with a Girdle of Spots[d]. They have ſeen ſome larger than the Earth[e]. What do I ſay? On *December* 21, 1719, one paſſed Southward thro' the middle of the Diſcus of the *Sun*, which was found by the Members of the Royal Academy of Sciences to be more than four times bigger than the Earth[f]. In 1714, they had obſerved one which might be 125 times bigger than the Earth[g]. And in 1706, there appeared a Collection of Spots, whoſe intire Maſs, if one ſuppoſe it ſpherical, ought to have been 1728 times bigger than the Earth[h]. It was only an inviſible Spot in the Sun.

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[*] 24 Converſ. Vol. I.

[a] Hiſt. de l'Acad. 1719. p. 74.

[b] Roſa Urſina, l. 1. Taq. Aſtr. l. 8. p. 344.

Ariſt. I am no longer aſtoniſhed that the *Sun* ſhould grow pale at *Cæſar*'s death. This paleneſs probably proceeded from ſeven or eight heaps of Spots diffuſed over the Diſcus of the *Sun* *.

Eudox. They ſaw in it, in 1716, eight different Collections of Spots, without obſerving any diminution of its Splendour; and the Paleneſs with which the *Sun* was covered at

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[c] Ibid. l. 2.

[d] Taq. Aſtr. l. 8. Tract. 3. n. 7. p. 344. Hiſt. de l'Acad. 1719. p. 75.

[e] Tacq. Aſtr. l. 8. p. 345.

[f] Hiſt. de l'Ac. 1720. p. 96.

[g] Hiſt. de l'Ac. 1719. p. 76. 1714. p. 79.

[h] Hiſt. de l'Ac. 1706. p. 123.

* Plin. l. 2. T. 1. c. 30.

Cæſar's death, might very well have had no other ſubſiſtence but in the imagination of Flatterers.

Eudox. But why may not thoſe apparent Spots, *Eudoxus*, be ſo many Planets which move like *Mercury*, round about the *Sun*?

Eudox. Planets would neither appear nor diſappear ſuddenly toward the middle of the *Sun*'s Diſcus, without ſhewing themſelves toward the Circumference; ſince Planets are all ſolid and durable Bodies. Now they have often ſeen Spots appear, and they have alſo ſeen them diſappear at once toward the middle of the *Sun*'s Diſcus, without having been ſeen toward the Extremities[i].

Ariſt. What then are theſe Spots? fixt Rocks; ſometimes covered with a luminous Liquid or inflamed Waves, and ſometimes diſcovered to the Eye?

Eudox. Bodies, which ſenſibly change their bigneſs and ſituation in regard of one another, are not Species of fixt and permanent Rocks. Now the Spots of the *Sun* change ſituation and bigneſs[k]. Some have been ſeen to increaſe ſo as to appear forty times larger than they appeared at firſt[l]. Theſe are probably new Productions, Foams floating upon the Surface of the *Sun*. The *Sun* muſt bear a reſemblance to an impure Liquor, which bubbles up and throws out Froth, and of the Froth which iſſues out of the *Sun*, muſt be formed opaque and black Bodies capable of ſtopping the Action of an infinity of Rays, of obſcuring divers parts of the *Sun*'s Surface, and of preſenting to our Eyes by that means divers heaps of Spots, ſome more obſcure, and others more clear.

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[i] Tacq. Aſtron. l. 8. Tract. 3. n. 7. Hiſt. de l'Ac. 1708. p. 107. 1706. p. 122. 1710. p. 111. 1705. p. 127. 1701. Mem. p. 39.

[k] Le P. Taquet. Aſtron. l. 8. Tract. 3. n. 7. Hiſt. de l'Ac. 1705. p. 127. 1708. p. 107.

[l] Hevelii Cometographia, l. 9. p. 711. l. 8. p. 478.

In ſhort, theſe ſorts of Froth may wander at the pleaſure of inflamed Waves, augment and diminiſh. Hence the changes of bigneſs and ſituations in the Spots. The Froth may come out of all parts of the *Sun*, as it comes out of bubbling Liquor. Hence the Spots which one ſees ariſe at once in divers parts of the *Sun*. The Action of the Liquid, which undermines them according to their Depth, may diſſolve, and at laſt render them imperceptible by diſſolution, and make them to paſs again into the Subſtance of the Liquid out of which they ſprung up like Froth out of a Liquor that boils. Hence the Spots diſappear at once.

The Spots of the *Sun* are generally environed with a kind of Cloudineſs, not ſo black as the Spots themſelves.

Ariſt. Becauſe probably the Extremities of the Spots are tranſparent, or are covered in part with a luminous Liquid. But have theſe Spots only irregular Motions?

Eudox. Ordinarily we ſee the Spots advance from the Eaſtern Limb of the *Sun* toward the Weſtern[m]. And often times have they been ſeen to make an intire Revolution round the *Sun* in about twenty ſeven days and an half[n].

Ariſt. Does the *Sun* itſelf then turn round upon its own Centre in twenty ſeven days and an half?

Eudox. The Spots of the *Sun* cannot, as they do, make a Revolution round the *Sun* in about twenty ſeven days and an half; that is, in twenty ſeven days, twelve hours, and 20′ or 30′, unleſs the *Sun* it ſelf turned upon its own Axis in the ſame Space, ſince they float upon the Liquid of this Planet. In ſhort, we perceive no interval between them and this Liquid. Being obſerved from divers parts of the Earth at the ſame time, they appear in the ſame point of the *Sun*. They find no leſs diſtance in them than in this Planet. Therefore the *Sun* turns round upon its own Axis in about twenty ſeven days and a half.

And it turns after ſuch a manner, that the upper part moves from Weſt to Eaſt, and the lower part from Eaſt to Weſt. For we only ſee the inferiour part, and we ſee the Spots move from the Eaſtern border of the *Sun* toward the Weſtern, and afterward to return again by the Eaſtern. And ſince Spots, which paſs through the Center of the *Sun*, in making their Revolution, deſcribe a Line which makes with the Plane of the Ecliptick an Angle of ſeven Degrees and an half, the Equator of the *Sun*, or the Plane of a Circle, which it deſcribes in its Revolution, muſt make, with the Ecliptick, an Angle of the ſame bigneſs[°].

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[m] Le P. Taquet. Aſtron. l. 8. Tract. 3. p. 7.

[n] Decouv. de la Lum. cél. qui paroît dans le Zodiaque, p. 17. Receuil d'Obſerv. Hiſt. de l'Acad. 1702. p. 73. 1706. p. 122.

Will you tell me, *Ariſtus*, why the Motion of the Spots appears ſlower toward the extremities of the *Sun*'s Diſcus than toward the middle?

Ariſt. As the *Sun* is round, and the Spots aſcend in regard to us, or deſcend toward the Borders, they are ſenſibly a longer time in the ſame viſual Rays, without producing conſiderable changes in the Eye. Hence their apparent ſlowneſs.

But, *Eudoxus*, could not our Eyes which have diſcovered what paſſes in the *Sun*, find ſomething ſingular in the Stars?

Eudox. Another day we ſhall ſpeak of the Stars. To-day let us talk of the *Dauphin*, who is the Object of our Vows. He is a new Sun, whoſe preſence will charm the People. Let us before-hand taſte the pleaſure which he is going to diffuſe over our Horizon.

[°] Scheiner. Roſa Urſina. Taquet. Aſtron. p. 345. M. Caſſini. Découv. de la Lum. cél. &c. p. 17, 63. Rec. d'Obſerv. par Meſſ. de l'Acad. Hiſt. de l'Acad. 1701. p. 105.

CONVERSATION XIV.

Upon the STARS.

Eudox. LET us, begin, *Ariſtus*, with calling to mind the Revolution of the Planets and the Sun, their Diſtance and Bigneſs; and the Knowledge of the Stars will thereby be rendered the more eaſy.

1. According to the Obſervations of the moſt skilful modern Aſtronomers, the Planets which turn upon their own Axes, as the Sun, make this Revolution after the ſame manner; ſo that the upper Hemiſphere moves from Weſt to Eaſt, and the lower Hemiſphere from Eaſt to Weſt, ſince we ſee their Spots move in the lower Hemiſphere from Eaſt to Weſt, diſappear in the Weſtern Limb, and appear again in the Eaſtern. The Satellites have alſo a Direction from the Weſt toward the Eaſt in the upper part of their Orb, and a contrary Direction in the lower*.

2. We know the diſtance of the Planets by the Parallax, Fig. 16. The Parallax is the

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* Hiſt. de l'Acad. 1707. p. 93. 1716. p. 57.

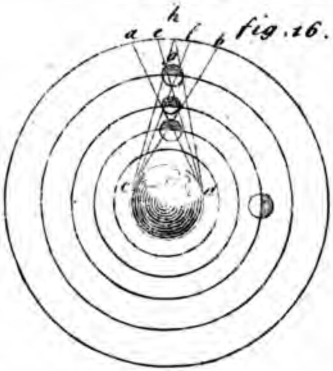

fig. 16.

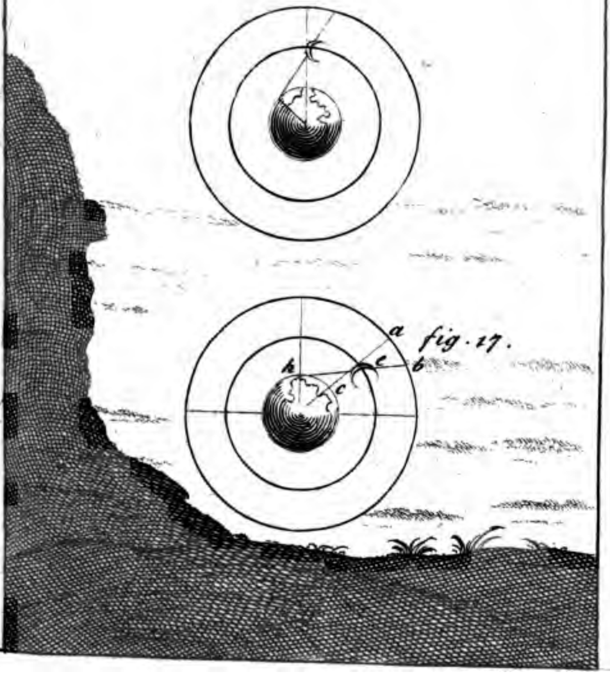

fig. 17.

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diſtance which we obſerve between two different Points of the Heaven (*a*, *b*) to which the ſame Object (*o*), ſeen at the ſame time by two Obſervators (*c*, *d*) is referred. The Parallax (*e f*) diminiſhes in proportion, as the Object (*g*) happens to be farther diſtant from the two Points where they make their Obſervations. Is the Object (*h*) at a certain diſtance? The viſual Rays which come to be re-united, no longer terminate in Points ſenſibly ſeparate, after they have croſs'd one another in the Object. The Obſervators ſee the Object in the ſame part of the Heavens. The greater ſenſible diſtance there is between the Points to which they refer, the greater is the Parallax.

Ariſt. But pray, what Method muſt we uſe to know the diſtance of the Stars by their Parallax?

Eudox. Let us ſuppoſe a Star, Fig. 17. the Moon (*e*) for example in the Horizon, and two Lines drawn to the Center of this Star, one of which proceeds from the Center (*f*) of the Earth, and the other from any Point (*h*) of its Surface, where there is an Obſervator. Thoſe two Lines or viſual Rays croſs one another in the Planet, and making a ſuperiour Angle (*a e b*) terminate in two different Points of the Heavens. This Angle, or the diſtance of thoſe two Points, (*a*, *b*), is the Parallax. The Angle (*f e h*) oppoſite at the Vertex, and formed by the two Lines which croſs one another in the Centre of the Planet, anſwers to this Parallax. Thoſe two Lines with the Semidiameter (*fh*) of the Earth, which is about 1500 Leagues, make a Rectangular Triangle, or which has a right Angle known; after the Angle (*feh*) oppoſite at the Vertex is known, we know two Angles. Now when we know two Angles of a Triangle, we know both the three Angles and the three Sides, and conſequently the Side (*cfe*) which is the Diſtance from the Center of the Earth to the Star. We know how many times this Side contains the Semidiameter (*fh*) of the Earth.

The Parallax varies in proportion as the Planet is more or leſs remote from us, they have found in the Moon about one degree of Parallax [p]; five and twenty Seconds in *Mars*, and Ten Seconds in the Sun [q].

Hence expert Aſtronomers place the Moon at 90 thouſand Leagues from the Earth [*], or

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[p] Découverte de la Lum. cél. &c. p. 22. Hiſt. de l'Acad. 1703. p. 16.

[q] Elém. d'Aſtron. par M. Caſſini. Rec. d'Obſ. Déc. de la Lum. cél. &c. p. 22. Sir Iſaac Newton. Greg. Aſtr. p. 336. Meſſ. de l'Acad. 1722. p. 227. 1726. p. 99.

[*] Let us ſuppoſe that the Semi-diameter of the Earth ſeen from the Sun be 11 Seconds, as it was lately collected from the Parallax of *Mars*, obſerved by Dr. *Halley* and Mr. *Pound*: and then the Earth's Diſtance will be nearly 20000 Semidiameters of the Earth, and the Moon will be leſs than *Mercury*. And the Proportion of the Diameter of the Earth to the Sun will be that of 1 to 83; to which Proportion we may give our Aſſent, till by an Obſervation of *Venus* in the Sun's Body, which will happen in 1761, we may be made more certain of the Sun's Parallax.

thereabouts[r]; *Mars* in Perigeon at 11 or 12 Millions of Leagues; *Venus* in Conjunction with the Sun at a diſtance ſomething leſs[ſ]; the Sun, at 33 Millions of Leagues[t]. They allow 24 or 25 Years for a Cannon Bullet, to

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Therefore the Diameter of the Sun is to the Planets Diameters, nearly in the Proportions repreſented in the following Table.

The Diameter of the Sun is to the Diameter of,	*Saturn,*	as 1000 is to	137
	Jupiter,		181
	Mars,		6
	the Earth,		12
	Venus,		12
	Mercury,		4

And becauſe the Spheres are to one another as the Cubes of their Diameters,

The Sun will be to	*Saturn;*	as 1000000000 is to	2571353
	Jupiter,		5929741
	Mars,		216
	the Earth,		1728
	Venus,		1728
	Mercury,		64

Hence it follows, that the Sun is a hundred and ſixteen times bigger than all the Planets put together. *Saturn* is 400 times leſs than the Sun: But for quantity of Matter, it is 2400 times leſs than the Matter of the Sun. *Jupiter* the biggeſt of all the Planets, is 160 times leſs than the Sun; and his Matter that compoſes his Body is 1033 times leſs than the Matter of the Sun. But our Earth, if it be compared with the Sun, is but of a very ſmall Magnitude, and not bigger than a phyſical Point; for it is 500000 times leſs than it. Beſides, comparing the Planets with one another, we find that *Jupiter* is bigger than all the reſt of the Planets put together; and that he is above 2000 times bigger than the Earth, but *Venus* is of the ſame bigneſs with the Earth. Yet there are two of the ſix Planets, *viz. Mercury* and *Mars*, leſs than the Earth. *Keil's Aſtronomy*, p. 344.

[r] Ricciol. Almag. T. 1. l. 6. c. 7. p. 418. n. 17. Hiſt. de l'Acad. 1722. p. 91.

[ſ] Mem. de l'Acad. 1722. p. 227.

[t] Elém. d'Aſtron. par M. Caſſini, p. 48. Découv. de la Lum. cél. p. 14. Hiſt. de l'Acad. 1706. p. 99.

go from the Earth to the Sun, or to come from the Sun to the Earth, always with the ſame Velocity [u]. There are ſome who make a Veſſel to ſail out of our Havens, and to arrive at ſome Spot of the Sun after a Navigation of eleven hundred Years at leaſt, in an immenſe Fluid [w].

Ariſt. This brings to my mind what *Pliny* ſays of a Stone, which fell down from the Sun into *Thrace* according to the Prediction of *Anaxagoras* [x]. No doubt *Anaxagoras* had ſeen in his Aſtronomical Obſervations, the Stone ſeparated from the Sun ſome hundreds of Years before the end of its fall.

Eudox. Probably *Anaxagoras* was too great a Philoſopher to make ſuch a Prediction. However that be; what time would a Veſſel require, was ſhe the beſt Sailer, to come from *Jupiter* and *Saturn*, eſpecially when they are in their Apogea, in order to bring us more certain News of thoſe Planets than what we have? They make the Diſtance of *Jupiter* from the Sun five times greater than that of the Earth, and that of *Saturn* about ten times [y]; Father *Riccioli* aſcribes to *Saturn* about 35 Millions of Leagues. After the moſt recent Obſervations, they make his Diſtance about three hundred and thirty millions of Leagues *.

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[u] M. Huygens.

[w] Nieuventit, p. 449.

[x] Book 2. ch. 58.

[y] Kepl. Epit. Aſtron. l. 4. p. 455. Riccioli l. 6. c. 7. p. 418. n. 17. Mem. de l'Acad. 1706. p. 97.

From the Diſtance and apparent bigneſs of Objects, they conclude their real Bigneſs. The Globe of the Moon appears to be about 60 times leſs than that of the Earth [a], a great Circle of which contains 9000 Leagues, as we have ſaid elſewhere [a], and the Semidiameter about 1500 Leagues. The Earth is alſo bigger than *Mercury*: but the Earth and *Venus* are almoſt of the ſame Diameter and Bigneſs. *Jupiter* and *Saturn*, whoſe Diameters are almoſt equal to one another [b], are about 1000 times bigger than the Earth [c]. As for the Sun, M. *Caſſini* found its Globe a Million of times bigger than the Earth [d].

This being granted, the Stars are like ſo many Suns. They are, I ſay, ſo many Species of Suns, if they are Luminaries very far diſtant, very large and luminous of themſelves †. But, 1. The Stars are luminous

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* M. de l'Acad. 1716. p. 56.

[a] Hiſt. de l'Acad. 1706. p. 109.

[a] 14 Converſat. T. 1.

[b] Hiſt. de l'Acad. 1716. p. 63.

[c] Ibid.

[d] 1707. p. 99.

† "That the fixed Stars are at an immenſe and inconceivable diſtance from us, may eaſily be collected from hence; that though by the Earth's annual Motion, we are nearer them by the whole length of the Diameter of the *magnus Orbis*, yet their ſituation or magnitude is not in the leaſt altered. And indeed it cannot be determined how great this diſtance is; becauſe there is no Parallax nor any other Method, whereby it can certainly be found out. Mr. *Huygens* thought of a very

Bodies very far diſtant; for they are infinitely

" ingenious way of making a Conjecture about it in his *Con-*
" *jectures concerning the Planetary Worlds.*" Book II. p. 125. *Thoſe,* ſays he, *who have hitherto undertook to calculate their Diſtance, have not been able perfectly to compaſs their Deſign, by reaſon of the extreme Niceneſs, and almoſt Impoſſibility of the Obſervations requiſite for their purpoſe. The only Method that I ſee remaining to come at any tolerable probability in ſo difficult a Caſe, I ſhall here make uſe of. Seeing then that the Stars, as I ſaid before, are ſo many Suns, if we do but ſuppoſe one of them equal to ours, it will follow, that its Diſtance from us, is as much greater than that of the Sun, as its apparent Diameter is leſs than the Diameter of the Sun. But the Stars, even thoſe of the firſt Magnitude, though viewed through a Teleſcope, are ſo very ſmall, that they ſeem only like ſo many ſhining Points, without any perceivable Breadth, ſo that ſuch Obſervations can here do us no good. When I ſaw this would not ſucceed, I ſtudied by what way I could ſo leſſen the Diameter of the Sun, as to make it not appear larger than the Dog, or any other of the chief Stars. To this purpoſe I cloſed one end of my twelve-foot Tube with a very thin Plate, in the middle of which I made a Hole not exceeding the twelfth part of a Line, that is, the hundred and forty-fourth part of an Inch. That end I turn'd to the Sun, placing my Eye at the other, and I could ſee ſo much of the Sun, as was in Diameter about the 182d part of the whole. But ſtill that little Piece of him was much brighter than the Dog-ſtar is in the cleareſt Night. I ſaw that this would not do, but that I muſt leſſen the Diameter of the Sun a great deal more. I made then ſuch another Hole in a Plate, and againſt it I placed a little round Glaſs that I had made uſe of in my Microſcopes, of much about the ſame Diameter with the former Hole. Then looking again towards the Sun, (taking care that no Light might come near my Eye to hinder my Obſervation) I found it appear of much the ſame clearneſs as* Sirius. *But computing according to the Rules of* Dioptricks, *I found his Diameter now was but* $\frac{1}{152}$ *part of that hundred and eighty ſecond part of his whole Diameter which I ſaw thorough the former Hole. Multiplying* $\frac{1}{152}$ *and* $\frac{1}{182}$ *into one another, the Product I found to be* $\frac{1}{27664}$. *The Sun therefore being contracted into ſuch a Compaſs, or being removed ſo far from us (for it's the ſame thing) as to make his Diameter but the 27664th part of that we every day ſee, will ſend us juſt the ſame Light as the Dog-ſtar now doth: And his Diſtance then from us will be to his preſent Diſtance undoubtedly, as 27664 is to 1; and his Diameter a little above four Thirds. 4'''. Seeing then* Sirius

is

ly beyond *Saturn,* ſince not only *Saturn,* whoſe

is ſuppoſed equal to the Sun, it follows that his Diameter is likewiſe $4'''$*, and that his Diſtance to the Diſtance of the Sun from us is as 27664 to 1. And what an incredible Diſtance that is, will appear by the ſame way of reaſoning that we uſed in meaſuring that of the Sun. For if twenty five Years are required for a Bullet out of a Cannon with its utmoſt ſwiftneſs, to travel from the Sun to us, then by multiplying the Number 27664 into 25, we ſhall find that ſuch a Bullet would ſpend almoſt ſeven hundred thouſand Years in its Journey between us and the neareſt of the fixed Stars. And yet when in a clear Night we look upon them, we cannot think them above ſome few Miles over our Heads. What I have here enquired into, is concerning the neareſt of them. For the other; ſince, it was before obſerved, they are ſo much farther removed into the Heavens, that the Diſtance of the neareſt from the following ones, is as great as the Diſtance of thoſe from the Sun, what an Immenſity muſt there ſtill remain?——When I have been reflecting thus with my ſelf, I thought all our Arithmetick was nothing, and that we are verſed but in the Rudiments of Numbers in compariſon of this great Sum.* This is indeed a very ingenious Conjecture of Mr. *Huygens.* But our *Flamſtead* has at laſt found, by wonderful diligent Obſervations, that the fixed Stars have an annual Parallax, which is a compleat Demonſtration of the Motion of the Earth. And that this Parallax is about $30''$.

But the following Particulars, which are worth Obſervation, are ſo many Conſequences of the vaſt Diſtance of the fixed Stars.

Firſt, If we were to approach ninety nine times nearer to the fixed Stars than we now are, ſo that we were diſtant from them but a hundredth part of the preſent Diſtance, we ſhould ſee them but a very little bigger than we do now; for they would appear no bigger, nor no otherwiſe than they do now, when looked at with a Teleſcope which magnifies the Object a hundred times.

Secondly, Nine parts at leaſt in Ten of that whole Space which is betwixt us and the fixed Stars, receive no more Light either from the Sun or from any of the fixed Stars, than we do from the Stars in a clear Night.

Thirdly, Light, (becauſe it is propagated from the Sun to the Earth, according to ſome in ſeven, and according to others in ten Minutes of time) cannot come from the fixed Stars to us in leſs than forty days time at the leaſt; and Sound could not come from thence to us in leſs time than fifty thouſand years;

whoſe Diſtance from the Earth is about 300 Millions of Leagues, eclipſes them, but the Teleſcope which magnifies the apparent Diſcus

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and a Ball ſhot out of a Cannon, would take up much longer time ſtill. See *Miſcel. Curioſ.* Vol. I. p. 277. And from hence the famous Mr. *Whiſton* draws a very ingenious Argument, which overthrows both the *Ptolemaick* and *Tychonick* Syſtems of the World. "If, *ſays he*, there be any difference in the Diſtances of the fixed Stars from us, and none of the *Ptolemaick* Aſtronomers have ventured peremptorily to affirm that there is not; then by reaſon of their vaſt Diſtances, the time which Light takes up in coming from a fixed Star to the Earth, muſt be very great, not to be meaſured by a few Hours or Days, but by whole Weeks or rather Months. Whence it will follow, that the true places of the fixed Stars, though they are both really and apparently in their proper Parallels of Declination; yet with reſpect to their right Aſcenſions, will very much differ from their apparent places, nor will any one of them, unleſs by great chance, ever be in that place, with reſpect to the Horizon or Meridian of the Earth where it appears to be. And beſides, it will follow from the difference of Diſtances, that the real Order and Situation of the fixed Stars, with regard to each other, is not ſuch as we ſee it from the Earth. We do indeed certainly know by Obſervation, the particular Parallel which any of them is in, becauſe the ſucceſſive propagation of Light does not at all diſturb their ſituation ſideways; but what their places are, with reſpect to each other in any parallel, cannot at all be known by Obſervation, unleſs we knew their Diſtances, and conſidered well what time Light would take to paſs through them, (which at preſent we do not.) Now ſince we know the places of the fixed Stars according to their Longitude and Latitude, only by having their places with reſpect to their right Aſcenſion and Declination given by Obſervation; it will certainly follow, that the real places of the fixed Stars can never be at all determined by us, the ſucceſſive motion of Light hindering it. Which ſtrange, or rather whimſical thing, in the antient Hypotheſis, has not been obſerved by any body (that I know of;) but I think it is very well worth the notice of the Followers of *Ptolemy* (if there remain any ſuch.) Wherefore I leave ſo ſtrange, and ſuch an inartificial Invention to be conſidered by them, and deſpiſed by you. *Aſtron. Lect.* p. 233.

of *Saturn,* 200 times[e], diminiſhes them inſtead of augmenting them, robbing them of their deceitful Ornament of Rays and Sparkling, and leaving them only, even ſuch of them as have the moſt apparent Bigneſs, a Diameter of ſome Seconds[f]: So that we imagine the Diſtance of the Dog-ſtar from the Earth, to be at leaſt 43700 times greater than that of the Earth from the Sun[g]. 2. The Stars are very great Luminaries, ſince they are ſtill perceivable notwithſtanding their enormous Diſtance. 3. The Stars are Bodies luminous of themſelves; for in a word, notwithſtanding their exceſſive Diſtance, we ſee them ſparkle and ſend forth Rays. Bodies which only reflected Light, would neither have Scintillation nor Radiation, at ſo prodigious a Diſtance. *Saturn,* which is only 300 millions of Leagues diſtant at moſt, neither ſparkles nor ſends forth Rays. Nor does the Moon, which is only diſtant from us about 90000 Leagues. Therefore the Stars are like ſo many Suns.

Ariſt. Is the Heaven then beſtrewed with an infinity of Suns?

Eudox. In that we are deceived. When we lift up our Eyes towards the Heaven in the Evening, we think that we ſee an infinite number of Stars, altho' with the naked Eye, skilful Aſtronomers have obſerved but 14 or

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[e] Mem. de l'Acad. 1717. p. 63.
[f] Ibid. p. 65.
[g] Ibid. 1720. p. 91.

15 hundred at moſt. When we turn our Eyes from one to another, the Impreſſion of the firſt ſtill ſubſiſts, ſometimes the very moment that we look upon the others. Thence the Illuſion. But with a Glaſs we ſee innumerable Stars, we diſcover more than 2000 in ſuch a Conſtellation [h].

A Conſtellation is a Collection, or certain Number of Stars; they count about 62 or 63 Conſtellations in the Heavens.

A Celeſtial Globe will ſooner teach you, or ſooner bring to your mind the Celeſtial Sphere, the Names and Situation of the different Conſtellations.

Ariſt. But, *Eudoxus*, why do we ſee more Stars upon the North-ſide than Southward [i]? Should not the Earth be in the middle of the World? Should it be nearer the South-Pole [k].

Eudox. The truth is, the South part has more Stars diſtinguiſh'd by their Splendour.

Ariſt. The Immobility of the Stars charms me as much as their Splendour. I admire this Spectacle continually uniform in the immenſe Regions, which hold the Stars as it were ſuſpended.

Eudox. What, on the contrary, ſurprizes and charms Aſtronomers, is to perceive prodigious changes in Spaces, which ſeem exempted from change. When we obſerve changes in thoſe Countreys, they ought to be enormous, however ſmall they may appear by reaſon of their immenſe Diſtance; and Aſtronomers diſcover ſome conſiderable ones. Some Stars diſappear, which the Ancients have ſeen. Some time ago they counted ſeven Stars in the *Pleiades*, and now we obſerve but ſix with the naked Eye. Some new ones appear. *Hyparchus* obſerved a new one 150 Years before the Birth of *Jeſus Chriſt*. They ſaw one almoſt as big as *Venus* in *Caſſiopæa* in 1572, which diſappeared without returning in 1574. The Years 1600 and 1604 preſented ſuch like Spectacles to the Eyes[l]. There are ſome Stars which diſappear and appear again, ſometimes bigger, ſometimes ſmaller[m]; ſome in very regular Periods, as the Star of *Balæna*, which is only viſible four Months and a half at moſt in one of its Revolutions, and whoſe Revolution is in about eleven Months; that of *Cygnus*, whoſe Revolution is in thirteen Months; and that of *Hydra*, whoſe Revolution is in two Years[n], and which is ſeen but about four Months during all that time[o]. There are ſcarcely any Conſtellations in which ſome ſenſible change does not happen in the ſpace of an hundred Years; and if any happen, it is eſpecially in the Milky Way, which is only a prodigious Collection of Stars[p].

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[h] Dans l'Orion. Reitha. p. 197. Radii Sydereo-Myſtici. Ric. Almag. l. 5. c. 6. p. 413.

[i] Ric. Alm. l. 6. c. 6. p. 413.

[k] Traité de la Peſanteur, par le P. Caſtel. T. 1. p. 138.

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[l] Hevelii Cometographia, l. 7. p. 374. Le P. Taquet. I. Aſtron. l. 8. Tract. 2. c. 1. de notis Stellis, n. 2. p. 332.

[m] Hiſt. de l'Acad. 1719. Mem. p. 95.

[n] Hiſt. de l'Acad. 1706. p. 111.

[o] 1709. p. 81.

Ariſt. But how can it be that antient Stars diſappear, and new ones appear, and that the ſame Stars appear and diſappear in very regular Revolutions?

Eudox. Froths and Spots yet larger than thoſe of the Sun, formed of ſulphurous and nitrous Materials, and ſpread over the Surface of the Stars, may incruſtate them, and hinder the inflamed Liquid from darting forth its Rays ſo far as our Eyes; and this is a diſappearing of the Stars. The inflamed, but incruſted Liquid, may undermine gradually by its continual agitation the Spots or Cruſts, and diſſipate them, or diffuſe it ſelf over them; and this is a new Appearance of Stars[*]. Finally, ſome Stars, may be only Half-ſuns compoſed of a ſolid and obſcure part, and of a liquid and luminous part, according to the ingenious Hypotheſis of M. *Boüillau*[q]. A Star of this Species turning upon its own Axis, preſents to our eyes ſometimes the luminous part which renders it viſible, and ſometimes the ſolid obſcure part which renders it inviſible to us; and this is the ſucceſſive appearance and diſappearance of a Star in its Revolution. A Star is a longer or ſhorter time viſible or inviſible, proportionally as the luminous part is larger or ſmaller than the obſcure part. Why in the Stars of *Hydra* and *Balæna* is the time of its being viſible ſhorter than that of the contrary? Becauſe the obſcure part is bigger than the other. Moreover the obſcure part may be compoſed of Spots, ſome of which are permanent, and others moveable; ſo that theſe ſometimes approach to, and ſometimes remove from the other. The luminous Liquid may have irregular Motions, poſſeſſing an extenſion ſometimes greater, ſometimes leſs upon the Surface of the Star. Hence the Changes of the bigneſs and duration in the Appearance of Stars.

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[p] Galilée in Nuncio Sydereo. Riccioli. T. 1. l. 6. p.412.

[*] The Appearance of new Stars (ſays Dr. *Clarke*) is much better accounted for from the Theory of Comets. For tho' ſome of the fixed Stars may be ſo very remote from us, as not to be ſeen by the help of our beſt Glaſſes, yet as they are fiery Bodies like the Sun, if any new Matter or Fewel be added to them, they may on a ſudden blaze out, ſo as to be ſeen by the naked Eye, brighter than any other Star; and as this Fewel is devoured, they may diminiſh in their Brightneſs, and by degrees return to their firſt inviſible State. And that Comets might probably ſupply them with this Fewel; ſee *Sir Iſaac Newton's Princip.* Book III. p.481. The Comet which appeared in 1680 in its Perihelion, was not ſo far diſtant from the Sun, as the ſixth part of the Sun's Diameter, and by reaſon of its very great Velocity in this nearneſs, and ſome Denſity that there is in the Sun's Atmoſphere,

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moſphere, it muſt meet with ſome Reſiſtance, and be a little retarded and approach nearer the Sun; and by approaching in this manner nearer and nearer to the Sun every Revolution, it muſt at laſt fall into the Body of the Sun. And in its Aphelion, where it moves ſloweſt, it may ſometimes be retarded by the Attraction of other Comets, and at ſome time or other fall into the Sun. And ſo the fix'd Stars likewiſe, which by degrees waſte themſelves by ſending forth Light and Vapours, may be ſupplied by Comets falling into them; and by the kindling of this new Fewel in them, they may be taken for new Stars.

[q] Bulliadi Monita duo. Journ. des Sçav. 1667. p. 11.

Stars appear leſs big and leſs numerous in a Summer Night, than in Winter.

Ariſt. Becauſe the Nights being darker in Winter, as the Sun is more ſunk below the Horizon, the Light of the Stars is leſs weakened by that of the Sun.

Eudox. Thus far we have endeavoured to penetrate into the Nature and Properties of the principal parts of the Univerſe. Let us now endeavour to diſcover their arrangement, that is to ſay, the true Syſtem of the World.

CONVERSATION XV.

Upon the Syſtems of the World.

Ariſt. TO attempt to diſcover the true Syſtem of the World, ſeems, *Eudoxus*, to be a fine, but difficult Enterprize; ſince the infinite Wiſdom of the Creator may produce the ſame Effects from different Cauſes.

Eudox. Let us recollect, *Ariſtus*, the moſt famous Syſtems; and in ſearching out the true one, we ſhall perhaps find at leaſt the moſt probable. But that we may the more certainly find it, let us begin with examining if there be any Vortices in the Univerſe. They call a Vortex * a liquid Maſs, whoſe parts are carried round a common Center.

Ariſt.

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* That the Vortexes of Matter in which the Planets ſwim, are mere Fictions, and contrary to the Phænomena of Nature; is evident from the following Arguments.

Firſt, The immenſe Space of the World is ſo far from being full of Matter (which imaginary Plenum is the ſole Foundation of the Fiction of Vortexes) that on the contrary, that Space which is filled with Matter, bears no proportion at all, to that immenſe Space which is void of all Matter. *Clark*'s *Rohault*. Vol. I. p. 27.

Secondly, It is evident from the Motion of Comets, which paſs very freely in the heavenly Spaces all ways, and from and to

Ariſt. For my part, I do not doubt, but that the *Earth, Sun, Jupiter* and *Saturn* have each of them their Vortex. Every one of theſe Bodies cannot be ſurrounded with a Fluid which turns round it as upon its Center without having its Vortex; ſince a Fluid whoſe parts all turn round a common Center, is a Vortex. Now, every one of theſe Bodies is environ'd with a Fluid which turns round it, as upon its Center. For it is certain that the Moon turns round the Earth, as upon its Center. *Mercury* and *Venus* after the ſame manner turn round the Sun; the Satellites of *Jupiter,*

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to all parts (in Orbs which cut the Planets Orbs at all Angles) that the Planets cannot be carried along by Vortices of Matter.

Thirdly, According to the Laws of Aſtronomy, a Body which revolves in an *Excentrick Orb,* moves ſlower in its *Aphelion,* and quicker in its *Perihelion;* but according to the Laws of Mechanicks, the Matter of the Vortex ought to move ſwifter where the place is ſtraiter and more *compreſſed,* that is in the *Aphelion,* than where the place is wider and *leſs compreſſed,* that is in the *Perihelion;* which two things contradict each other. Thus in the beginning of the Sign *Virgo,* where the Aphelion of *Mars* now is, the Diſtance betwixt the Orbs of *Mars* and *Venus,* is to the Diſtance between the ſame Orb in the Beginning of the Sign *Piſces* in the proportion of three to two very nearly: And therefore the Matter of the Vortex contained between thoſe two Orbs, ought to move ſwifter in the Beginning of *Piſces,* than in the Beginning of *Virgo,* in the ſame Proportion of three to two; for the ſtraiter the Space is, through which the ſame Quantity of Matter paſſes in the ſame time of one Revolution, with ſo much the greater Velocity ought it to paſs. If therefore the Earth were carried along in this Celeſtial Matter, being relatively at Reſt with it, and revolved together with it about the Sun; its Velocity in the Beginning of *Piſces,* would be to its Velocity in the Beginning of *Virgo,* in a ſeſqui-alterate Ratio: whence the apparent Diurnal Motion of the Sun in the Beginning of *Virgo,* would be more than ſeventy Minutes, and in the Beginning *piter*, round *Jupiter*; thoſe of *Saturn*, round their primary Planet [a]; and every one of thoſe Luminaries ſwim in a Fluid, which turns round as they do. Every one of them ſwims in a Fluid, ſince they all remit the Light to our Eyes, and Light is a fluid Body. The Fluid in which theſe Stars are carried, turns round as they do. Otherwiſe they muſt inceſſantly communicate of their Motion to divide it, they would loſe it proportionally, and conſequently their Motion would become ſlower. It never does grow ſlower: Therefore the *Earth*, *Sun*, *Jupiter*, and *Saturn* have each of them their Vortex.

Beginning of *Piſces* leſs than forty eight Minutes. Whereas we find, by experience, the apparent Motion of the Sun is greater in the beginning of *Piſces*, than in the beginning of *Virgo*, and therefore the Earth moves ſwifter in the beginning of *Virgo*, than in the beginning of *Piſces*. The Hypotheſis therefore of Vortexes directly contradicts the Aſtronomical Phænomena, and tends more to confound the Celeſtial Motions than to explain them. *See Newt. Princip. Book* II. *Schol.* 10. *Prop.* LIII.

Fourthly, If three equal round Veſſels be filled, the one with Water, the other with Oil, the third with molten Pitch, and the Liquors be ſtirred about alike to give them a vortical Motion; the Pitch by its Tenacity will loſe its Motion quickly; the Oil being leſs tenacious, will keep it longer; and the Water being leaſt tenacious, will keep it longeſt, but yet will loſe it in a ſhort time. Whence it is eaſy to underſtand, that if many contiguous Vortices of molten Pitch, were each of them as large as thoſe which ſome ſuppoſe to revolve about the Sun and fix'd Stars, yet theſe, and all their parts, would by their Tenacity and Stiffneſs, communicate their Motion to one another, till they all reſted among themſelves. Vortices of Oil or Water, or ſome fluider Matter, might continue longer in Motion; but unleſs the Matter were void of all Tenacity and Attrition of Parts, and Communication of Motion (which is not to be ſuppoſed) the Motion would conſtantly decay. *Opticks*, p. 374.

[a] 13 Converſ. Vol. III. p. 194.

Is it not alſo probable enough, that the Stars, or at leaſt ſome Stars, have likewiſe their Vortices? for in a word, 1. We diſcern their Scintillation at an immenſe diſtance; and the Revolution of luminous Bodies upon their Center, ſucceſſively offering to our Eyes different parts, ſometimes more luminous, and ſometimes leſs bright, ought to contribute very much to render their Radiation ſenſible*. 2. The various Phaſes and Revolutions of the Stars of *Hydra*, *Cygnus* and *Balæna* are ſufficient Proofs that they turn upon their own Axes. And can they turn round after that manner, unleſs the Fluid which ſurrounds them turn about in like manner? Therefore it is probable enough that the Stars, at leaſt ſome of them, have alſo their Vortices.

Eudox. Notwithſtanding your Reaſons, *Ariſtus*, many Perſons will probably ſtill believe that thoſe Vortices have ſcarcely any exiſtence but in the Imagination.

Ariſt. However that be, *Eudoxus*, do you oblige us at preſent with a ſhort Deſcription of the moſt famous Syſtems.

Eudox. Theſe are the Syſtems of *Ptolemy*, *Copernicus* and *Tycho*.

Ptolemy placed the Earth in the Center of the World, and made to turn round it, in ſo many concentric Circles, and in this Order, beginning with the Planet neareſt the *Earth* (*t*) Fig. 18. the *Moon* (*l*), *Mercury* (*m*), *Venus* (*u*), the

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* Riccioli Almag. T. 1. l. 6. p. 397.

fig. 18.

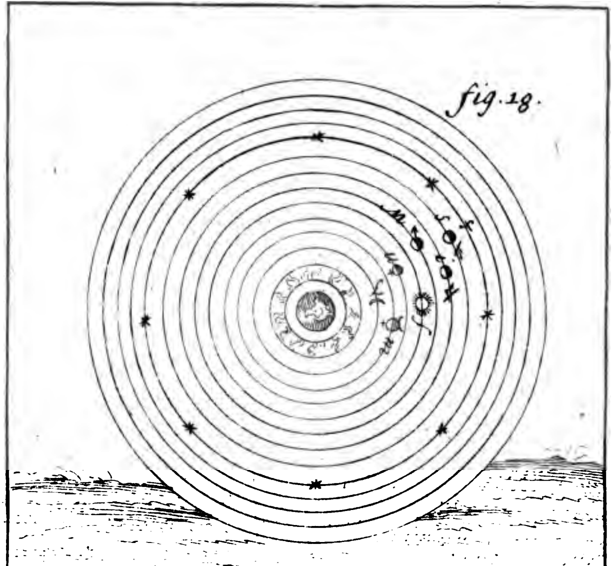
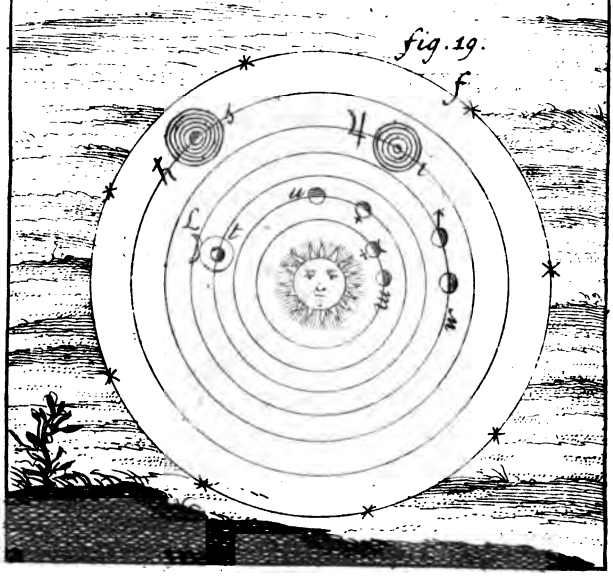


fig. 19.



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the *Sun* (*S*), *Mars* (*M*), *Jupiter* (*i*), *Saturn* (*s*), the *Firmament* (*f*).

Ariſt. A Syſtem, in which *Mercury* and *Venus* have not the Sun for the Center of their Motion, cannot be ſupported; for we ſee thoſe Planets ſometimes below the Sun, and ſometimes above it, and ſometimes in a mean Diſtance, without *Mercury*'s being at any time diſtant from the Sun above 28 Degrees, or *Venus* above 48; as we have already ſaid *. Now in the Syſtem of *Ptolemy*, *Mercury* and *Venus* have not the Sun for the Center of their Motion, ſince they are placed in inferiour Orbits. Therefore *Ptolemy*'s Syſtem is inſupportable.

Eudox. Accordingly, *Copernicus* could not bear with it; and not only did he make *Mercury* and *Venus* turn round the Sun, but preſumed alſo to tranſpoſe the Earth and Sun, to place the Sun in the Center of the World, and the Earth in the place of the Sun among the Planets, to make a Planet of the Earth, and a fixt Star of the Sun. For according to the Syſtem of this illuſtrious Aſtronomer, the Sun (*S*) is immoveable, or without any progreſſive Motion in the Center of the World; and the Planets revolve about this Luminary, in this Order, Fig. 19. *Mercury* (*m*); *Venus* (*u*); the Earth (*t*) in an Ecliptick with the Moon (*l*) carried about, as a Satelles, in the Vortex of the Earth; *Mars* (*M*); *Jupiter* (*i*);

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* 12 Converſ. Vol. III.

Saturn (*s*). The Firmament (*f*), which encloſes them, has only an appearance from Eaſt to Weſt.

The Center of the Sun, and the Center of the Earth are always in the Ecliptick, or the Earth has two Motions, one annual round the Sun, and the other diurnal upon its own Axis; ſo that the Equator of the Earth makes with the Plane of the Ecliptick, or the Axis of the Earth with the Axis of the Ecliptick, an Angle of 23 Degrees 30′.

Deſcartes, and the new Philoſophers, have improv'd the Syſtem of *Copernicus*. In the improv'd Syſtem, if the Sun is not in the Center of the World, he is at leaſt in the Center, or near the Center of his Vortex, to which he communicates Agitation, Fig. 20. The Planets carried along by the Motion of the Vortex are therein elevated more or leſs in proportion to their bigneſs, or ſolidity, their centrifugal Force; and accompliſh their Circuits in more or leſs time, according as they are greater or ſmaller.

Ariſt. The Earth is a little degraded in this Syſtem; but it appears ſimple and natural.

Eudox. *Tycho* quickly avenged the Earth by replacing it in the Center of the World, and remitting the Sun to the Order of the Planets. Nevertheleſs he left him *Mercury* and *Venus* for Satellites. Therefore this Aſtronomer's Syſtem places the Earth (*t*), Fig. 21. in the Center of the World, and makes to revolve round fig: 20.

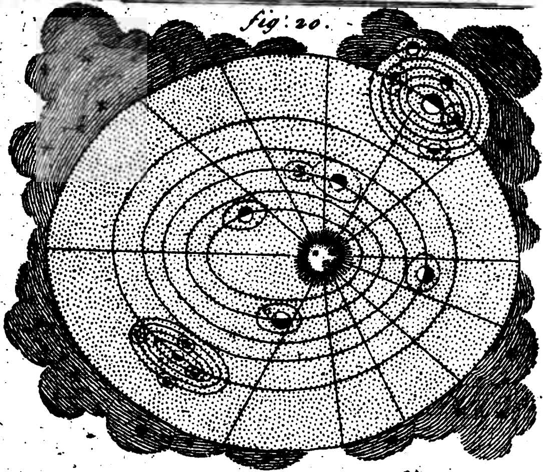
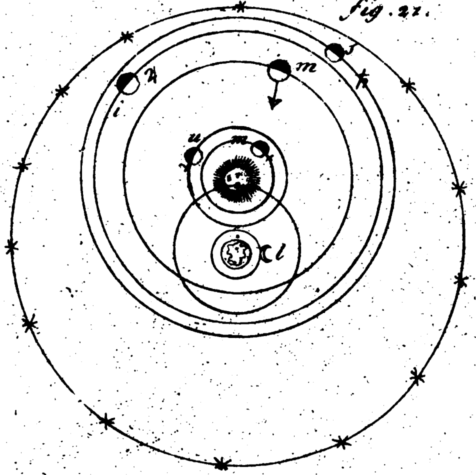


fig. 21.



round it, in this Order, the Moon (*l*); the Sun (*S*), with *Mercury* (*m*), and *Venus* (*u*), his Satellites; *Mars* (*M*); *Jupiter* (*i*), and *Saturn* (*s*), encompaſſed with the Firmament (*f*), or with thoſe immenſe and liquid Regions, wherein the Stars ſeem ſuſpended.

Ariſt. But what was it in the Hypotheſis of *Copernicus*, which ſhock'd *Tycho* ſo much?

Eudox. I am ſenſible, *Ariſtus*, that you have a Taſte for this Hypotheſis. Probably you would be charmed to ſee your ſelf carried upon the Earth, as upon ſome large Veſſel, to ſail into thoſe vaſt Spaces, and to make a Circle round the Sun every Year, whoſe Diameter would be about 66 Millions of Leagues at leaſt. But if you turned round the Sun with the Earth, would you not be afraid leſt ſooner or later you ſhould ſee your ſelf precipitated with the Earth into the Flames of this Luminary?

Ariſt. They ſeem not to fear the fall of *Jupiter*, whoſe Globe is a thouſand times bigger than the Earth; why then ſhould I fear the fall of the Earth?

Eudox. Would you quietly make about two hundred millions of Leagues, in running through the annual Circle of the Earth?

Ariſt. I ſhould not ſo much as perceive it. One might make a compleat tour round the Earth aboard a Veſſel, without obſerving one's circular Motion; becauſe the ſame parts of the Veſſel always preſent, and the Reſemblance of the parts of the Water, would make no ſenſible change in the Eye. By the ſame reaſon one might quietly make two hundred millions of Leagues round about the Sun without perceiving it.

Eudox. Some new Stars, or the ſame, which ſometimes would appear larger, ſometimes ſmaller, and the Pole ſometimes more, ſometimes leſs elevated with reſpect to us, in proportion as you approached to the ſuperiour or inferiour part of the Earth's Orbit, would make you to obſerve your Revolution round about the Sun.

Ariſt. I ſhould perceive no difference, neither in the Stars, nor in the Pole, ſuppoſing that the Earth were entirely parallel, or nearly ſo to it ſelf, and that the Circle, whoſe Diameter was 66 millions of Leagues, were only a Point in regard of its diſtance from the Stars. But the Earth would be always parallel to it ſelf; neither the annual Motion, nor the velocity of Motion is contrary to the Paralleliſm of the Earth. And its great Circle, after all, would only be a Point in regard of its diſtance from the Stars. For, Objects diminiſh in relative bigneſs in proportion to their diſtance *; and the diſtance of the terreſtrial Orbit from the fixt Stars may be look'd upon as immenſe, ſince the Stars, far from augmenting, diminiſh in bigneſs by Glaſſes, and the moſt skilful Aſtronomers are inclined to place the Dog-ſtar at more than 40 thouſand

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* 20 Converſ. Vol. II.

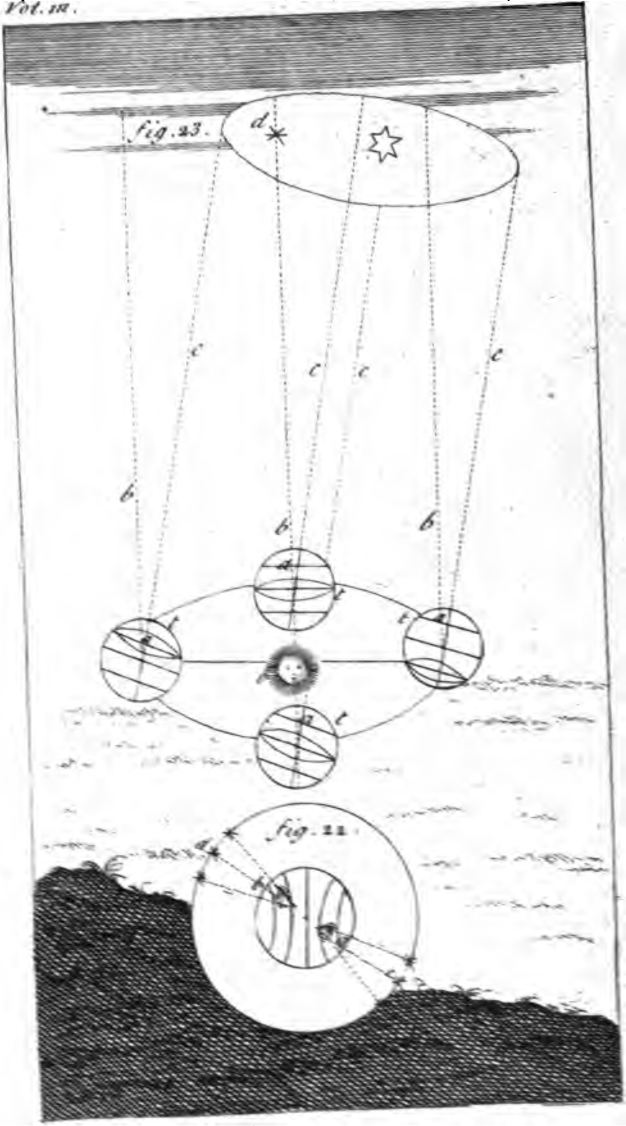

fig. 23.

fig. 22

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times 33 million of Leagues from hence. Therefore, I ſhould ſee no difference either in the Pole, or in the Stars.

Eudox. Two Men in the two temperate Zones of the Earth ſee different Vertical Stars, and very far diſtant from one another. They ſee, the one the North-Pole, and the other the South-Pole. And in two Points diametrically oppoſite, of a Circle whoſe Diameter was 66 millions of Leagues, at 66 millions of Leagues diſtance from yourſelf, would you always ſee both the ſame Stars and the ſame Pole?

Ariſt. The viſual Rays (*a b*) Fig. 22. of thoſe two Men placed in oppoſite Zones, far from being parallel, when they view the Heavens, are very diverging, becauſe of the curvature of the Earth; they diverge ſtill more and more, and terminate in places (*c*, *d*) of the Heaven very remote from one another. On the contrary, as I ſhould be always at the ſame place (*a*) Fig. 23. of the Earth's Surface (*t*), in oppoſite Points of its Circle, my viſual Rays (*b*) would always be parallel to one another, the Axis (*c*) of the Earth being always parallel to itſelf. And conſequently they would at laſt be ſenſibly re-united at the ſame ſenſible Point (*d*) of the Heaven, like two Rows of Trees of a long Avenue, which tho' parallel ſeem at laſt to be united; becauſe the Angle of Viſion formed by the viſual Rays, which terminate at the Extremities of the Avenue, proceeding continually in diminiſhing, in proportion as the diſtance of the Object augments, becomes at laſt nothing, or imperceptible *. Therefore the two Men would ſee different Stars and different Poles; and I ſhould every where ſee the ſame Pole, and the ſame vertical Stars. Every where ſhould I ſee the ſame Luminaries roll over my head.

Eudox. I know not whether you could explain, according to this Principle, the appearance of the diurnal Motion of the Stars, Planets, and Sun, from Eaſt to Weſt.

Ariſt. When you go on board a Veſſel from the Weſt toward the Eaſt, you would ſay that the Banks, Trees and Rocks advanced from the Eaſt toward the Weſt, becauſe they ſucceſſively preſent new parts to your Eyes, which paint themſelves ſucceſſively in divers parts of your Organs; ſo that at firſt they are referred toward the Eaſt, according to the Rules of Opticks, and after that, toward the Weſt. By the ſame principle, if the Earth in 24 hours makes a Revolution upon its own Axis from Weſt to Eaſt by its diurnal Motion, we ought to obſerve in the immoveable or much ſlower Stars, the appearance of a contrary Motion.

Eudox. If the Earth revolved upon its own Axis after that manner, and conſequently we made daily upon our Axis 9000 Leagues, ought we not to be ſenſible of it?

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* 10 Converſ. Vol. II.

fig. 25.

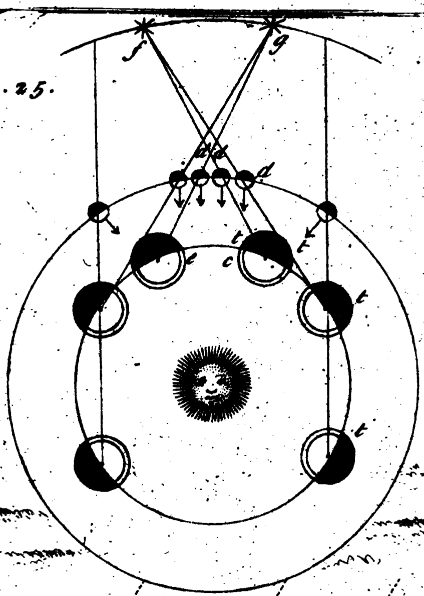
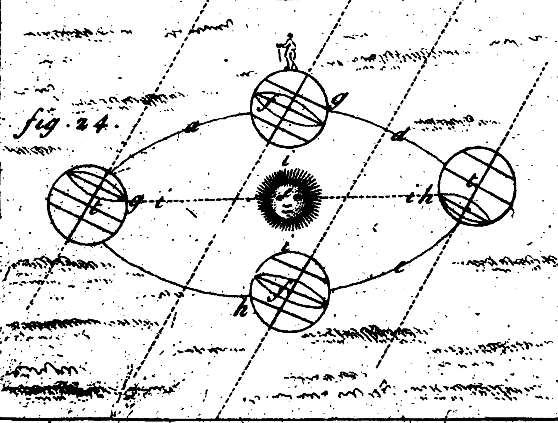


fig. 24.



Ariſt. We might, as we have already remarked, go round the Earth in a Veſſel, without obſerving the Progreſſion of the Veſſel; becauſe the continual preſence of the ſame Veſſel, ſurrounded with ſimilar parts of Water, make no changes in the Eye capable of informing us thereof. Why ſhould we perceive the Motion of the Earth, ſince it would always ſtrike the Senſes after the ſame manner?

Eudox. I ſee very well upon this Principle the viciſſitudes of Day and Night. In proportion as the Earth in its Revolution of 24 Hours preſented to the Sun ſucceſſively one Hemiſphere, it would withdraw the other. The Light would be diffuſed upon the Hemiſphere, which faced the Sun; and the other would be covered with Darkneſs. Hence, Day and Night. But how ſhall we find the different Seaſons in this Hypotheſis?

Ariſt. As the Center (*t*) of the Earth is always in the Ecliptick (*abcd*) Fig. 24. as well as the Center of the Sun (*e*), and the Plane of the Ecliptick cuts the Equator (*f*) of the Earth in two oppoſite Points, and paſſes thro' the two terreſtrial Tropics (*g h*), the Line or the Ray (*i*), which comes from the Center of the Sun to that of the Earth in its continual Revolution, twice encounters the terreſtrial Equator (*f*), upon the Surface of the Earth; and this is the Time of the Equinoxes, and the beginning of Spring or Autumn; of the Spring, when the direct Ray ought to approach us; and of Autumn, when this Ray ought to remove from us. It reaches the Tropick of *Cancer* (*g*) once, and this is the Summer Solſtice, or the beginning of Summer in regard of us, ſince this Ray can come no nearer to us; once the Tropic of *Capricorn* (*k*), and this is the Winter Solſtice, or the beginning of Winter with reſpect to us, ſince this Ray can remove no farther from us.

Eudox. You will alſo find, no doubt, in the unequal Revolutions of the Planets round the Sun, their Directions, Stations, and Retrogradations; and theſe will only be Appearances.

Ariſt. They ſay that the Planets are *Direct*, when we ſee them advance from the Weſt toward the Eaſt, according to the Order of the Signs of the Zodiack; *Stationary*, when they ſeem to ſtay in the ſame part of the Heavens; *Retrograde*, when they appear to retire toward the Weſt. Now, this may happen from the inequality of their Velocity. They run thro' their Orbits in unequal times. This inequality is the Cauſe why the Earth paſſes more frequently, or more rarely between the Sun and the ſuperiour Planets, during their Revolution, and why the inferiour Planets, namely *Mercury* and *Venus*, paſs more frequently or more rarely between the Earth and the Sun. Wherefore, 1. The Earth follows, overtakes, and precedes the ſuperiour Planets (*ab*) Fig. 25. If the Earth (*t*) follows a Planet (*d*), the Planet appears *direct*. Does the Earth (*c*) overtake a Planet (*d*)? The Planet appears *ſtationary*; becauſe the exceſs of Velocity, which happens in the Earth, renders the Motion of the Planet imperceptible toward the ſame place, and makes the Eye refer it for ſome time to the ſame place (*f*) of the Heaven. Does the Earth (*e*) precede the Planet (*d*) conſiderably? The Eyes refer the Planet to a more remote part of the Heavens (*g*), and it ſeems *retrograde*. 2. We ſee thoſe Appearances in the ſuperiour Planets, becauſe they compleat their Orbits more ſlowly than the Earth. They obſerve thoſe Appearances in the inferiour Planets, becauſe they make their Revolutions round the Sun more ſwiftly than the Earth. By reaſon of this exceſs of Velocity, ſometimes they go before the Earth from Weſt to Eaſt, and appear *direct*. Sometimes they are in Conjunction in the ſame Line with regard to ſome Sign, going toward the ſame part; and they ſeem *ſtationary*. Sometimes in the inferiour part of their Circle, they paſs again from Eaſt to Weſt, leaving the Earth very far behind them, and they are *retrograde*. Hence, the different Appearance of *Directions*, *Stations*, and *Retrogradations*.

Eudox. Theſe Appearances are more frequent in a Revolution of *Saturn*, than in one of *Jupiter*, and in one of *Jupiter* than in one of *Mars*.

Ariſt. As the Earth makes a Revolution in a Year, *Mars* in two, *Jupiter* in twelve, *Saturn* in thirty, and conſequently *Saturn* has leſs relative Motion than *Jupiter*; *Jupiter* than *Mars*; and *Mars* than the *Earth*; the *Earth* overtakes and precedes *Saturn* oftner in a Revolution than *Jupiter*; and *Jupiter* than *Mars*. Hence the Appearances of *Retrogradations* are more frequent in *Saturn* than in *Jupiter*, and in *Jupiter* than *Mars*.

Eudox. They ought therefore to be alſo more frequent in *Venus* than in *Mercury*; ſince *Venus* takes more time to run through her Orbit than *Mercury*.

Ariſt. This exceſs of Velocity in *Mercury* cannot bring him oftner back toward the Weſt than *Venus*, unleſs he appear oftner *Retrograde*. Now this exceſs of Velocity does bring him oftner again toward the Weſt in the inferiour part of his Circle. Therefore, &c.

Eudox. But why does *Mars* being *Retrograde*, deſcribe a greater Arc, than *Jupiter*; and *Jupiter* a greater, than *Saturn*?

Ariſt. The viſual Ray (*a*) Fig. 26. which goes toward a direct Planet (*b*) and the Ray (*c*), which goes toward a *Retrograde* Planet (*b*), cut one another in the Center of the Planet; and after they have croſs'd one another, they terminate in different parts (*d*, *e*) of the Heaven. The Arc (*d*, *e*) contained between the two diverging Rays, is the Arc of *Retrogradation*. This being granted; the Arc of *Retrogradation* (*d*, *e*) is ſo much the larger, the nearer the Earth the Rays cut one another in the Center of the Planet (*b*); and ſo much

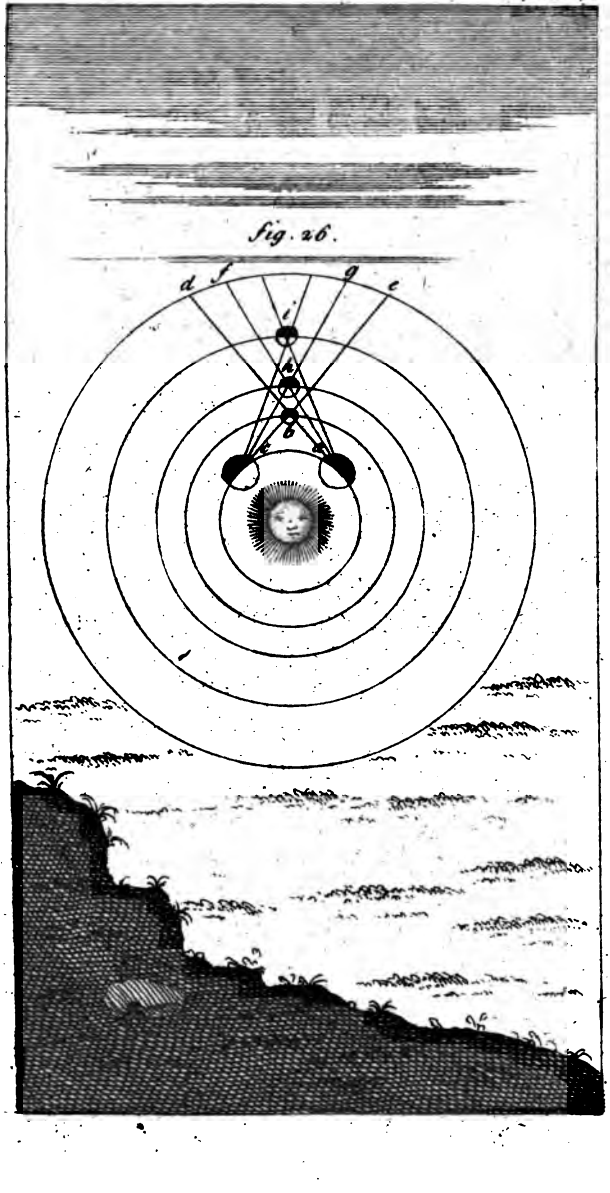


Fig. 26.

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the leſs (*fg*), the farther diſtant from the Earth the Center of the Planet (*h*) is; ſince Angles formed by viſual Rays diminiſh proportionally as the Objects remove *. Now, *Mars* (*b*) is nearer the Earth than *Jupiter* (*h*), and *Jupiter* (*h*) is nearer than *Saturn* (*i*). Therefore the Arc deſcribed by *Mars* when *retrograde*, ought to be greater than that of *Jupiter*, &c.

Eudox. But *Mars* in Perigeon is nearer the Earth than *Mars* in Apogeon, notwithſtanding the Arc of *Retrogradation* in *Mars* in Perigeon, is leſs than in *Mars* in Apogeon, according to the Obſervations of *Kepler*. Why does this exceſs of Proximity diminiſh his Arc of Retrogradation, inſtead of augmenting it?

Ariſt. If *Mars* in Perigeon had the ſame relative Velocity as the Earth, or if in the ſame time he deſcribed an Arc, which anſwered to that of the Earth, he would not appear *retrograde*, notwithſtanding his exceſs of Proximity. Conſequently if the exceſs of Velocity of *Mars* in Perigeon, above *Mars* in Apogeon, ſurpaſs the exceſs of the Proximity to the Earth, the Arc of *Retrogradation* ought to be ſmaller in *Mars* in Perigeon, than in *Mars* in Apogeon. But, according to the Obſervations of *Kepler*, the exceſs of Velocity in *Mars* in Perigeon, ſurpaſſes his exceſs of Proximity to the Earth, either becauſe he is in the ſmalleſt part of his Orbit, or becauſe he is at the ſame time nearer the Sun, and the Center of his Motion.

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* 10 Converſ. Vol. II.

Eudox. What you ſay is ingenious; but it ſuppoſes the immobility of the fixed Stars, and yet they move upon the Poles of the Ecliptick, always parallel to the Ecliptick, from Weſt to Eaſt. For the firſt Star of *Aries*, which was 330 Years before *J. C.* at the Interſection of the Ecliptick and Equator, was advanc'd ſix Degrees 40′ in the time of *Ptolemy* [b]. It is at preſent at 29 Degrees toward the Eaſt, ſtill placed above the Ecliptick, and it makes about one Degree in 70 Years [c]: ſo that the Sun returns to the Interſection of the Ecliptick and Equator, or to the Point of the Equinox, almoſt a Month before he overtakes a Star which was found there about two thouſand Years ago; and this is what they call the *Anticipation* or *Preceſſion* of *Equinoxes*. Conſequently the fixt Stars are not properly fixt; and they make an intire Revolution in 25200 Years [d], or thereabouts [e]. In ſhort, the ſame fixt ones continually remove from, or approach to the Pole of the Equator. The Polar Star, which in the time of *Eudoxus* was twelve Degrees diſtant

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[b] Hiſt. de l'Acad. 1708. p. 96.

[c] Tycho, Gaſſendi, Riccioli Almag. l. 6. c. 16. Hiſt. de l'Acad. 1708. p. 94, 96. Caſſini Hiſt. de l'Acad. 1708. p. 94.

[d] According to Caſſini, Hiſt. de l'Acad. 1708. p. 94.

[e] According to Tycho, in 25806; according to Gaſſendi, in 25000; according to Riccioli, in 25920. Almag. T. 1. l. 6. c. 16. p. 445, 446, 447.

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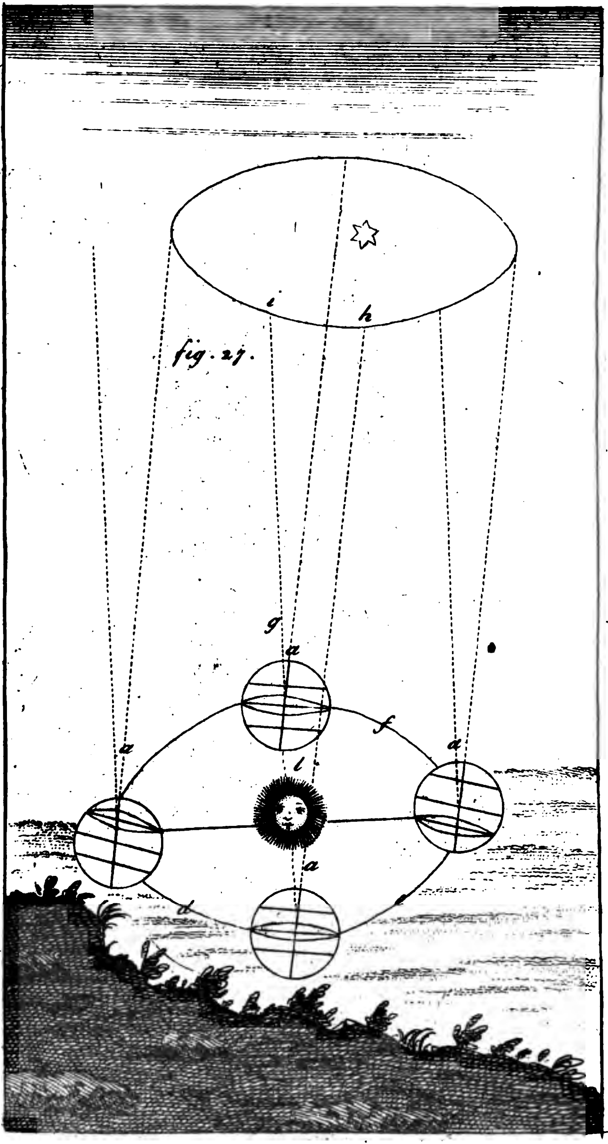

fig. 27.

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from the Pole of the Equator [f], is now not farther diſtant than two Degrees 18 Minutes [g].

Ariſt. If we may ſuppoſe that the Motion of the Stars upon the Ecliptick, or parallel to the Ecliptick, is only in Appearance, the Objection is vain; but we may ſuppoſe it. For, the Axis (*a*), Fig. 27. of the Diurnal Motion, or of the Equator of the Earth, being always 23 Degrees and an half inclined upon the Plane of the Ecliptick (*c d e f*), the Axis of the Equator (*a*), and the Axis of the Ecliptick (*g*), cut one another after ſuch a manner as to determine theſe fixt Stars in the Heaven; the one, the Pole of the Terreſtrial Equator (*h*), and the other the Pole of the Ecliptick (*i*), making together an Angle (*h i l*) of twenty three Degrees and an half. Suppoſe the Pole of the Equator turns round the Pole of the Ecliptick from Eaſt to Weſt, ſo that it always makes with it an Angle of twenty three Degrees and an half; the Equator of the Earth will always change with reſpect to the Heavens, and will paſs thro' other fixed Stars, while the Ecliptick of the Earth, whoſe Axis is immoveable, will make no change in the Heaven. The Equator of the Earth will cut the Ecliptick in Points more Weſtward; and conſequently the fixt Stars, which will always be in the ſame Points of the immoveable Ecliptick, will appear to remove from the Interſection, and to advance from Weſt to Eaſt one Degree in ſeventy Years, and to accompliſh their Circle in 25200, or thereabouts.

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[f] Ric. Almag. Nov. T. 1. l. 6. c. 4. p. 404, 405.

[g] Hiſt. de l'Acad. 1708. p. 94.

Eudox. But the Axis of the Terreſtrial Equator cannot move after this manner, without ceaſing to be parallel to it ſelf in its different Situations.

Ariſt. That is true; but a defect of Parallelism, which is only fifty one Seconds diſtributed into a whole Year, is imperceptible. Now the defect of Paralleliſm, in the Hypotheſis which we are now ſpeaking of, is only fifty one Seconds, by reaſon of the extreme ſlowneſs of the circular Motion of the Axis of the terreſtrial Equator round its Ecliptick *.

Eudox. As for the Perigeon and Apogeon of *Mars*, *Jupiter*, and *Saturn*, and the difference of their apparent Bigneſs in their different Situations, we comprehend them immediately.

Ariſt. As the Earth is very far diſtant from the Sun, which is in the Center of the Vortex, the Perigeon of *Mars*, *Jupiter*, and *Saturn*, happens when they are in Oppoſition, or when the Earth is between them and the Sun. Their Apogeon happens, when they are in Conjunction, or when the Sun happens to be between them and the Earth. They appear bigger in their Perigeon, and ſmaller in their Apogeon; becauſe Objects increaſe or diminiſh in ſize, in proportion to their diſtances[h].

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* Hiſt. de l'Acad. 1708. p. 96.

Eudox. It muſt be allowed Aſtronomy is ſufficiently to be accounted for by the Hypotheſis of *Copernicus*: but we ſhall ſee what Method you will take to reconcile it with Philoſophy.

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[h] 20 Converſ. Vol. II.

CONVERSATION XVI.

Upon the Syſtem of COPERNICUS.

Eudox. KEPLER's Rule, ſo famous among the Aſtronomers, and which ſeems to favour the Hypotheſis of *Copernicus*, does it not alſo ſeem to overthrow it?

Ariſt. Pray, *Eudoxus*, begin with giving me ſome Idea of this Rule *.

Eudox. They call a *Square* Number the Product of a Number multiplied by it ſelf; a *Cube* the Product of a Square multiplied by the firſt Number; the *Square Root*, a Number whoſe Multiplication gives the Square; the *Cube Root*, a Number, whoſe Square multiplied by the ſaid Number gives the Cube. For example, four is the Square of two; eight the Cube of two; two the Square Root of four, and the Cube Root of eight.

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* See Notes to Converſat. 21. *infra.*

This being granted; What is *Kepler*'s Rule? It is a Rule, which expreſſes the Proportion that is between the Diſtances of the Planets from the Sun and their Revolutions; and here it is: “The diſtances of Planets from the Sun are to one another, as the Cube Roots of the Squares of their Revolutions [a] [*]: Call to mind in the firſt place the Duration of thoſe Revolutions [b]. The Numbers, which expreſs this Duration, being multiplied, every one by themſelves, ſee what are the Cube Roots of the Products or Squares. Theſe Roots expreſs the difference of the diſtances.

For Example, 1, 12, 30, expreſs the Duration of the Revolutions of the Earth, *Jupiter* and *Saturn*; ſince in the Hypotheſis of *Copernicus* and *Kepler*, the Earth compleats its Revolution round the Sun in a Year, *Jupiter* in 12, and *Saturn* in 30, or thereabouts. Multiply ſeparately 1 by 1, 12 by 12, and 30 by 30: you have 1 the Product of 1 by 1; 144, the Product of 12 by 12; and 900, the Product of 30 by 30. 1, 144, 900 are the Squares of 1, 12, and 30.

What are now the cubical Roots of theſe Squares? 1; 5, a little more; and 10, a little leſs. For 1, the Product of 1 by 1, only gives 1; 5 multiplied by 5 gives 25, and 25 multiplied by 5 gives 125, a little leſs than 144; 10 multiplied by 10 gives 100, and 100 multiplied by 10 gives 1000, and conſequently 900, a little more. Therefore the cubical Roots of 1, 12, 30 are about 1, 5, 10.

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[a] Kepl. Epit. Aſtron. l. 4. p. 455. Hiſt. de l'Acad. 1705. p. 118. Mem. 1716. p. 217, 219.

[b] 17 Converſ. p. 189. T. 3.

[*] See Notes to Converſat. 21. *infra*.

Hence, 1, 5, 10, or thereabouts, expreſs the Diſtances of the Earth, *Jupiter* and *Saturn* from the Sun. Theſe Diſtances are as 1, 5, 10, or thereabouts. The Diſtance of *Saturn* from the *Sun* is about 10 times as great as that of the Earth; the diſtance of *Jupiter*, 5 times 5 the diſtance of *Mars*, at leaſt one time and an half; the diſtance of *Venus*, about 3 fourths of that of the Earth; the Diſtance of *Mercury* a third [c]. Is the Diſtance of the Earth from the Sun 33 Millions of Leagues [d]? That of *Saturn* will be ten times 33 Millions of Leagues, a little leſs, or about 300 Millions of Leagues; that of *Jupiter*, 5 times 33 Millions of Leagues, or 165 Millions of Leagues, *&c.*

Ariſt. I think I underſtand the famous Rule.

Eudox. They pretend that this Rule is confirmed by eleven Planets, whoſe diſtances, in regard of a common Center, and Revolutions round about this Center, are known immediately even by Obſervation. Theſe eleven Planets are *Mercury* and *Venus*, the four Satellites of *Jupiter*, and five of *Saturn* [e].

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[c] Kepl. Epit. Aſtron. p. 455.

[d] 14 Converſ. Vol. 3.

Ariſt. You ſeem, *Eudoxus*, to make uſe of *Kepler*'s Rule in a Deſign of combating the Syſtem of *Copernicus*; but does it not confirm the ſame? It cannot overturn the Syſtem of *Tycho*, without confirming that of *Copernicus*: now it overturns, or at leaſt ſeems to overturn that of *Tycho*. The Rule is falſe, or the Syſtem is falſe: it is falſe, I ſay, or the Syſtem is falſe, if in this Syſtem it aſcribes to the Sun and Moon a proportion of Diſtance from the Earth incomparably leſs than it really is; but it gives ſuch a Proportion. For according to *Tycho*, the Moon and Sun turn round the Earth, the Moon in one Month, and the Sun in twelve. The cubical Roots of the Squares of 1 and 12 being 1, and a little more than 5, the diſtances of the Moon and Sun from the Earth ought to be, according to *Kepler*'s Rule, as 1 and 5, or thereabouts; wherefore the Sun would only be about five times farther diſtant from the Earth than the Moon: but this Proportion of diſtance is incomparably leſs than the real Proportion; ſince the Moon has one degree of Parallax, and the Sun has at moſt 10, according to the moſt ſkilful Aſtronomers. Therefore *Kepler*'s Rule, if one ſuppoſe it true, confirms the Syſtem of *Copernicus*.

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[e] Hiſt. de l'Acad. 1705. p. 118, 119.

Eudox. And for my part, I ſay, that ſuppoſing it true, and that the Circles of the Planets have the Sun for their common Center, as in the Hypotheſis of *Copernicus*, the Laws of Phyſicks are thereby deſtroyed. For according to this Rule, the real Velocities of Planets will always be greater, proportionally as the Planets ſhall be nearer the Center or the Sun. Theſe Velocities will anſwer to the Roots of the reciprocal Diſtances. The real Velocities of the Planets will diminiſh proportionally as the Planets ſhall be farther diſtant. Their Velocities will be about the half leſs than their diſtances. For example, a Planet four times farther diſtant from the Sun than another, will have two times leſs Velocity.

Ariſt. The Planets effectually diminiſh in real Velocity, in proportion as they are diſtant from the Sun[f]. *Mercury* makes his Revolution round the Sun in almoſt 3 Months, and is about three times nearer the Sun than the Earth; conſequently the Earth ought to compleat its Revolution round the Sun in 9 Months, in order to equal the Velocity of *Mercury*. It only compleats it in 12, therefore it has leſs real Velocity. The ſame is the Caſe with *Venus*. And the ſame thing is obſerved in the ſubaltern Planets, that is in the four Satellites of *Jupiter* and five of *Saturn*, whoſe Diſtances from a common Center we immediately perceive. We ſee the ſame Planet augment in Velocity in proportion as it approaches to its Perihelion, or on the contrary. Does the Sun approach his Perigeon? We ſee his Velocity augment more than his Diameter; and conſequently the Augmentation of Velocity is not a ſimple Appearance cauſed by a greater Proximity. Therefore there muſt be ſomething real in it; and if the Earth move, it really moves more ſwiftly, when it is nearer the Sun. Therefore the Planets have ſo much the more Velocity, the leſs diſtant they are from this Luminary.

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[f] M. Caſſini, du Progrès de l'Aſt. p. 36.

Eudox. This being granted; a Syſtem, in which the inferiour Planets ought to come out of their Spheres, paſs off toward the Extremities of the Vortex, and make the ſuperiour Planets to deſcend into their Place, is a Syſtem which has no foundation: But this is what ought to happen in the Hypotheſis of *Copernicus.* The inferiour Planets having more Velocity, have a greater central or centrifugal Force, in order to paſs off toward the Extremities of the Vortex.

Ariſt. The exceſs of Velocity, which is in the inferiour Planets, does not give them a greater central Force than that of the ſuperiour Planets, if the ſuperiour Planets have an exceſs of Maſs or Solidity, greater than this exceſs of Velocity; ſince the Motion, and conſequently the centrifugal Force, is equally meaſured both by the Maſs, Solidity, and Velocity,

locity [g], and a Body larger or more ſolid, has leſs Surface in regard of its Maſs [h], has its Force leſs diſtributed, and unites the more of it for the producing of the ſame effect. Now the ſuperiour Planets may have an exceſs of Maſs or Solidity, greater than the exceſs of Velocity, which is in the inferiour Planets.

Eudox. But the Earth is almoſt of the ſame bulk as *Venus*; and that of *Mars* is at leaſt ſeven or eight times leſs than that of the Earth, or of *Venus*. How then can the Earth have more Maſs or Solidity, more central Force than *Venus*; and *Mars*, more than the Earth?

Ariſt. Neither the equality nor exceſs of Bulk makes the equality or exceſs of Solidity or Maſs. The Earth may be more maſſy and ſolid than *Venus*, tho' it is nearly of the ſame Diameter. *Mars* it ſelf may be more maſſy and ſolid than the Earth, tho' it is much ſmaller. We may ſay that *Mars* exceeds *Venus* and the Earth in Solidity, in proportion as its Velocity, or exceſs of Diſtance from the Sun, affords it leſs centrifugal Force. We may ſay as much of every part of the Fluid, which compoſes the ſpherical Surface in which *Mars* moves.

Eudox. The Sun muſt be in the Center of the Vortex; the Matter, which occurs toward the Center, muſt be the fineſt and moſt agitated Matter of the Vortex; and it muſt always become more and more denſe toward the Extremities. But how can that be? A Volume of this more ſubtile and agitated Matter, would have more centrifugal Force, than an equal Volume of globulous Matter, and which one ſuppoſed more condenſed, ſince it would have more Velocity, and as much Maſs in effect; for there is no vacuity.

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[g] 7 Converſ. Vol. 1.
[h] 8 Converſ. Vol. 1.

Ariſt. Two equal Volumes, the one of finer Matter, and the other of Matter more compact and ſolid, have an equal number of determinate parts. Nevertheleſs that whoſe Matter is more ſolid, may have more central Force, even with leſs Velocity; becauſe its Force being leſs diſtributed, leſs diſſipated, or more united, contributes more to produce the ſame effect. Divide a ſmall Ball into a great quantity of Particles: theſe Particles have all together leſs efficacy to remove from the ſame Center, than they had formerly when united in the ſame ſolid Maſs; becauſe formerly all their Forces conſpired to the ſame effect; and after diviſion, they not only direct their Action towards different parts, to the left, to the right, upwards, and downwards; but they have beſides more Surface in proportion to their Maſs. Therefore the fineſt and moſt agitated parts of the Vortex, ought not to have a greater central Force than the others.

Eudox. But, *Ariſtus*, whence can this exceſs of Velocity proceed in thoſe Circles of etherial Matter, in proportion as they approach to the Sun?

Ariſt. From the Action of the Sun itſelf upon them, which ought to abate in proportion as it paſſes into the upper and larger Circles, and is communicated to a great number of parts.

Eudox. I don't at all ſee upon thoſe principles what can determine the Planets to cut the Ecliptick at different Angles. How can the Orbits of *Mercury* make with the Ecliptick an Angle of ſix Degrees, the Circle of *Venus* an Angle of three Degrees and an half, that of *Mars* an Angle of 1 Degree 50 Minutes, and that of *Saturn* an Angle of 2 Degres 50 Minutes[1].

Ariſt. Different Boats * and different ſolid Bodies being abandoned to the Current of a River, receive from it Directions which cut the middle of the River at various Angles, according as the Bodies preſent to the Current different Figures, more or leſs unequal Parts, different Situations, or as Brooks or Torrents enter into the River with divers Directions. May not one ſay as much of the Planets carried in the etherial Matter?

Eudox. But if the Equator of the Sun, or the great Circle which it deſcribes in revolving upon its own Axis, makes with the Ecliptick an Angle of ſeven Degrees and an half, or thereabouts, as ſome skilful Aſtronomers have obſerved [k], the Planets carried in the Sun's Vortex, ought I think to deſcribe Orbits parallel to the Sun's Equator, and all of them to make with the Ecliptick the ſame Angle.

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[1] M. Villemot. p. 150.

* See Notes to Converſ. 15. *ſupra*, and 21. *infra*.

Ariſt. The difference of Figure in different Planets, the difference of Solidity in the parts of the ſame Planet, and different Situations in regard of the Current of etherial Matter, may determine it to give them Directions, which are not parallel to the Sun's Equator, but which carry the Earth through the Ecliptick, and make the Ecliptick to be cut by the other Planets; as the difference of Figure, Solidity, and Situation in divers Boats, determine the Current of the River to give them different Directions, ſome parallel to the Axis of the River, and others variouſly inclined to this Axis.

Eudox. Do you believe then, *Ariſtus*, that a Body as big as the Earth can naturally turn round the Sun?

Ariſt. Jupiter and *Saturn*, 1000 times bigger than the Earth, inceſſantly turn round the Sun; why may not the Earth turn round after the ſame manner?

Eudox. Thoſe who are under the Equator would make 9000 Leagues every day, without being ſenſible of it, by turning round upon the Axis of the Earth.

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[k] *Father* Scheiner. J. M. Caſſini, Découv. de la Lum. cél; &c. p. 17. Rec. d'Obſerv. par les Meſſ. de l'Acad.

Ariſt. We make 100 Leagues in 24 hours aboard a Veſſel, without being ſenſible of it; why might we not inſenſibly make 9000 Leagues with the Earth? As the Atmoſphere would turn round as ſwiftly as the Earth, this Revolution would not cauſe any change in the Eyes, and would be perfectly imperceptible.

Eudox. Turning one's ſelf round about for ſome few Moments, dazzles one; and would not turning round 9000 Leagues in twenty four hours cauſe any dazzling?

Ariſt. When one turns one's ſelf rapidly about, new Objects ſtrike the Eyes every moment; the ſucceſſive, quick and repeated action of thoſe Objects upon the Senſes, cauſes therein ſome changes, dazzlings. The Direction which the Animal Spirits have acquired, ſubſiſts for ſome time after one has ceaſed to turn round; and hence every thing ſeems ſtill to turn round about you. But one may make 9000 Leagues with the Earth, without ceaſing to ſee the ſame Objects, and without any change, any alteration being made in the Senſes.

Eudox. At leaſt the Weſtern Mountains would appear to be elevated, or to aſcend every inſtant.

Ariſt. To aſcend with reſpect to us, is to approach our Zenith. Now the Weſtern Mountains would not approach our Zenith, ſince it would advance toward the Eaſt proportionally as we our ſelves advanc'd toward the ſame part; the Zenith is moveable. It is always the moſt elevated Point, which is directly over our heads. And this ſeems to me ſufficient for ſhewing that the Hypotheſis of *Copernicus* may be ſupported as an Hypotheſis; at leaſt it is what they ſay in favour of this Hypotheſis.

Eudox. It is ingenious. It explains the Phænomena of Nature, at leaſt the moſt part of them. Nevertheleſs, notwithſtanding the biaſs I ſee you have towards it, I believe you will adhere to the Hypotheſis of *Tycho* a little changed, as well as I, in our next Converſation.

CONVERSATION XVII.

Upon the Syſtem of TYCHO.

Ariſt. CONFESS, *Eudoxus*, the great Circle, which they make the Earth deſcribe in the Syſtem of *Copernicus*, frightens you. You are afraid to expoſe your ſelf to the making ſo much way in ſo little time.

Eudox. The enormous way which one makes in ſo ſhort a time in this Hypotheſis, does not at all alarm me; and beſides, I ſhould make it as ſpeedily as you. But a Syſtem which appears more conformable to the Scripture *, and which at the ſame time is reconciled with the principal Phænomena of Nature, ought to pleaſe me better. Now, 1. The

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* As the *Copernican* Syſtem is demonſtrably true, all the Remarks we ſhall ſubjoin to this Converſation, is what follows from the learned Dr. *John Clarke*. It is evident, ſays he, from a curſory View of the Old and New Teſtament, that they are Miſcellaneous Books, containing great variety of Things, and taking in a large compaſs of Time; ſome parts of which are Hiſtory, others writ in a Poetical Style, and others Prophetical: But the Deſign of them all is profeſſedly to recommend the Practice of true Religion and Virtue. It is with this View therefore that we are to underſtand any Expreſſion contained in them. This Method we naturally take with reſpect to all other Books.

Syſtem

Books. No one reads a Treatiſe of Philoſophy, but he expects to find that the Terms mentioned there, be uſed in a Philoſophical Senſe; and accordingly he always apprehends them ſo. But if in ſuch a Treatiſe there ſhould *incidentally* be brought in ſomething upon a different Subject, and deſcribed according to the *Vulgar* way of ſpeaking, without any regard to *philoſophical* Truth; he would not pretend to explain ſuch an occaſional Diſcourſe in the ſame manner as he did the reſt of the Book. And the like holds true with regard to the Scriptures. They are not Books of Metaphyſicks and Philoſophy, deſign'd to entertain Men's Curioſity with nice Speculations; but they are Books of Religion and Morality, calculated for the regulation of Mens Behaviour and Practice. And becauſe no Language abounds with Words ſufficient to expreſs the Particulars of all Sciences, therefore ſome of them muſt neceſſarily be uſed in different Senſes as they relate to different Subjects. The common People, in thoſe things they are converſant about, and have occaſion to take notice of, expreſs things as they appear to the Senſes, and not as what in ſtrictneſs and reality they are; which is ſufficient for the purpoſes of Life. But whoever would enquire into the Truth of ſuch Things, and examine the Foundation of ſuch Appearances, muſt expreſs himſelf very differently, therefore there muſt be both a *vulgar* and *philoſophical* way of expreſſing the ſame thing; which whoever confounds or miſapplies, immediately introduces innumerable Abſurdities. Theſe Diſtinctions have place in the forementioned Books; and the not attending to theſe Diſtinctions, has rendered many things there utterly unintelligible, and others contrary to Fact and Experience. For want of attending hereto, ſome Perſons have laboured under inextricable Difficulties how to reconcile ſome of the moſt certain Truths in the natural Syſtem of the World, ſuch as the Motion of the Earth and the like, with the Repreſentation made of them in Scripture; Whereas upon this ſingle Suppoſition, that the Scripture is a Book of *Morality*, and not of *Philoſophy*, it ought to be very exact in conforming all its Words and Expreſſions to the *moral* or *religious* Senſe of them; but the other being foreign to this Subject, and only occaſionally introduced, there is no need of ſuch accuracy in them, but they *may* ſafely, nay it would be abſurd if they ſhould *not*, be delivered according to the vulgar acceptation of Words; as not being at all intended to inform Men in thoſe Matters. Every Difficulty upon this account immediately vaniſhes. *Boyle's Lectures*, vol. 2. p. 57, &c.

Syſtem of *Tycho*, which fixes the Earth, and makes all the Luminaries to revolve round it, ſeems more conformable to Scripture. "God, "ſays the Scripture *, has fix'd the vaſt Body "of the Earth, ſo that it ſhall not be ſhaken. "The Sun riſes and ſets; and returns to the "Place whence he came, in the ſame Place "he riſes again. He takes his Courſe toward "the South, and turns toward the North †."

2. In this Syſtem we ſee the Cauſes of the principal Phænomena. The diurnal Motion of the Sun, from Eaſt to Weſt, makes the Days; his Revolution from Weſt to Eaſt, according to the Order of the Signs of the *Zodiack*, makes the Years: his ſucceſſive Poſitions in *Aries*, *Cancer*, *Libra*, and *Capricorn*, make the different Seaſons; the Excentricity of the Circles of the Planets makes their Apogeon and Perigeon; the ſpiral Lines of the ſuperiour Planets, and the Revolutions of the inferiour round the Sun, make the Directions, Stations, and Retrogradations. The Planets ſituated in the upper part (*a*) of their Epicycles are direct, ſince then one ſees them advance from Weſt to Eaſt, Fig. 28. In the inferiour part (*b*), they are retrograde; then they come from the Eaſt toward the Weſt. While they aſcend (*c*) or deſcend (*d*), you ſay that they are ſtationary; becauſe being then in a part of their Circle, almoſt parallel to

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* Pſ. 92. ver. 2.

† Eccleſiaſt. chap. 1. ver. 5.

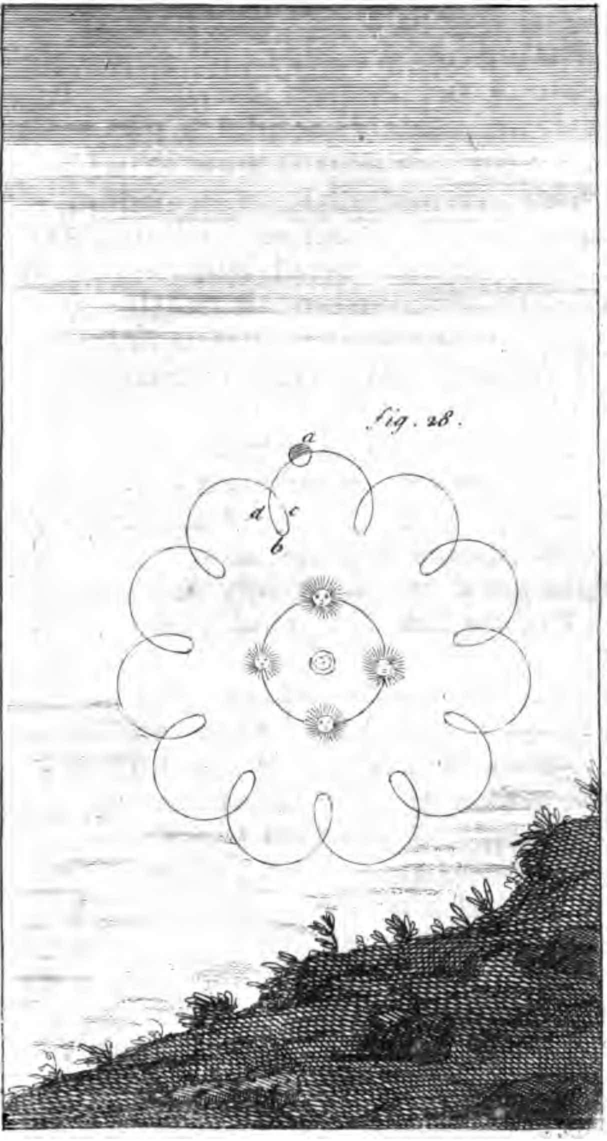

fig. 28.

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to the viſual Ray, their Motion is imperceptible.

The Directions, Stations, and Retrogradations of the inferiour Planets, and a great number of other Phænomena, are explained as in the Syſtem of *Copernicus*. Therefore I chuſe to hold by the Syſtem of *Tycho*, eſpecially if they change ſome Circumſtances. In this Hypotheſis, the Sun carries along both the inferiour and ſuperiour Planets, while the Earth remains immoveable between thoſe Planets.

Ariſt. Philoſophy ſuffers a little in ſeeing the Earth immoveable in this Situation. How is it that the Impreſſion, which paſſes from the Sun into the inferiour Planets, as far as the ſuperiour Planets, is not communicated to the Earth, being free and placed in the middle?

Eudox. The Impreſſion of the Sun's Revolution may either be extended to the Earth, or to the ſuperiour Planets; and one may ſay, that they are moved by the Impreſſion, which they received at firſt from the Author of Nature, who preſerves this Impreſſion.

Ariſt. But can it be that a Liquid, which contains the Moon, Sun and Planets, ſhould turn round the Earth, without the Earth's turning round?

Eudox. Oftentimes the ſuperiour part of the Atmoſphere runs from Weſt to Eaſt, without its Action deſcending to the Earth; ſince we often ſee Clouds ſtrongly elevated advance rapidly toward the Eaſt, while we ſee the inferiour Clouds very quiet. Therefore it is not neceſſary, that the turning round of a Liquid infinitely diſtant from us, ſhould be communicated ſo far as to the Earth.

Ariſt. At leaſt, the Luminaries would have two oppoſite Motions at a time, the one from Eaſt to Weſt, and the other from Weſt to Eaſt.

Eudox. 1. The one is a common Motion, the other proper; and two Motions of this kind are not incompatible. One walks from the Eaſt toward the Weſt, upon a Veſſel carried from the Weſt toward the Eaſt. 2. Thoſe two Motions of the Luminaries are not directly oppoſite; ſince they cut one another, making an Angle of 23 Degrees and an half. But I ſee, *Ariſtus*, I may ſay what I will, the Simplicity of *Copernicus*, and a certain Air of Novelty, affect you. For my part, I will ſay of the Sun, as *David* did, "He "comes forth full of ardour to run his race "like a Giant. He proceeds from one end "of the Heaven, and arrives at the other*."

Ariſt. I will glory in thinking and ſpeaking as you do.

Eudox. Finally, *Ariſtus*, the Eclipſes of the Luminaries, and the Comets, would alſo deſerve ſome particular Converſations, as I think.

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* Pſ. 18. 7.

Ariſt. I ſhall willingly explain myſelf upon the Eclipſes, and gladly hear you upon what concerns Comets.

——Dulces ante omnia Muſæ.
————————————monſtrent
Defectus ſolis varios, Lunæque labores *.

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* Virg. l. 2. Georg. v. 475, 477, 478.

CONVERSATION XVIII.

Upon Eclipſes of the SUN.

Ariſt. WHEN one has ſome Idea of the Arrangement, and relative Situation of the Luminaries, that the Sun or the Earth is in the Center of the World, or of our Vortex; it is eaſy to comprehend the Eclipſes. They call an Eclipſe, the fleeting Diſappearance of a Luminary, cauſed by the Interpoſition of an opaque Body, of the Earth, or of ſome Planet. Now, as the Planets are ſuſpended above one another in unequal and concentric Orbits, which cut one another in oppoſite Points, and encloſe the Earth, it is natural, that from time to time ſome of them meet in the ſame viſual Rays with ſuperiour Luminaries, and deprive us of the Light of thoſe Luminaries by their Denſity. Hence, the Eclipſes of the Sun, Moon, Planets, both ſuperiour and inferiour, the Satellites, and the Stars.

Eudox. Let us begin with the moſt affecting Eclipſes. What is it that cauſes the Eclipſes of the Sun with regard to us?

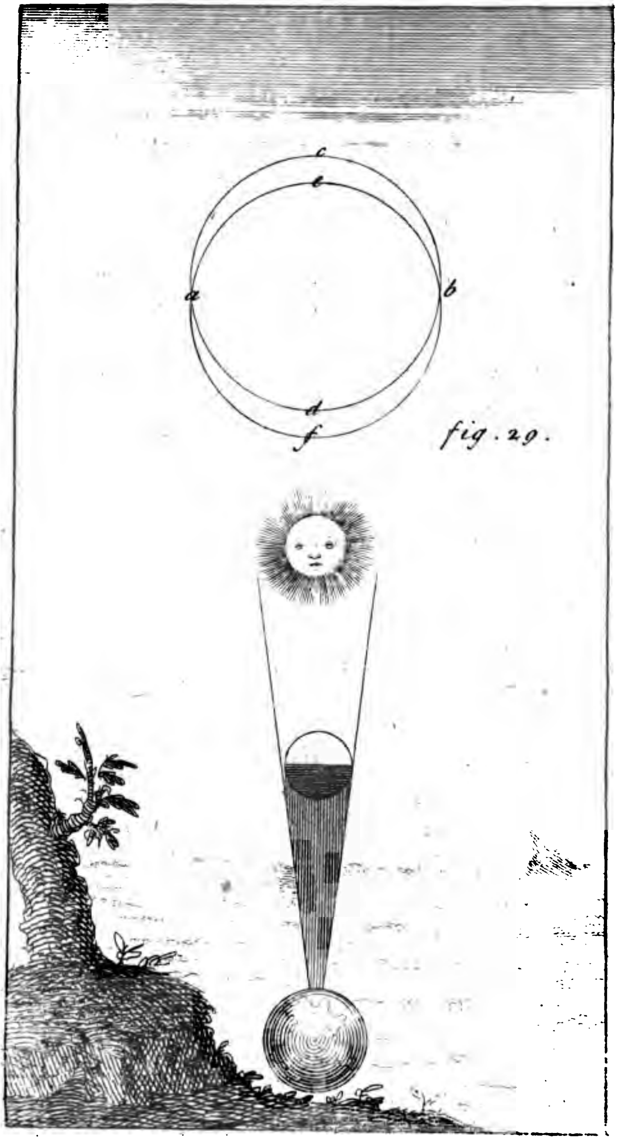

fig. 29.

Ariſt. The Interpoſition of the Moon, which inceſſantly revolves round the Earth, as a Satelles of the Earth, and paſſes between the Sun and us. Is the Moon directly between us and the Sun? She hides this Luminary from our Eyes; or, which is the ſame thing, ſhe caſts her Shadow over us: and this is an Eclipſe of the Sun, with reſpect to us. Accordingly the Eclipſes of the Sun happen only in the Conjunctions, or at the New Moons; that is, when the Moon is interpoſed between the Earth and the Sun; and the Eclipſe anſwers to the Situation of the Moon, with reſpect to the Sun, and our Eyes.

Eudox. But why do not Eclipſes of the Sun happen in all New Moons? We ſeldom obſerve above two or three in a Year.

Ariſt. The Orbit (*a c b d*) of the Moon, cuts the Ecliptick (*a e b f*) in two oppoſite Points (*a*, *b*) Fig. 28. making with this Circle Angles of about five Degrees *. They call thoſe Points or Sections, Nodes, or the Head and Tail of the Dragon. The one (*a*) of the Nodes they call the aſcending Node, or the Head of the Dragon. The other (*b*), the deſcending Node, or the Tail of the Dragon. The firſt is the Section thro' which the Moon paſſes from the South towards the North; and the ſecond is the Section thro' which the Moon paſſes from the North toward the South; two changing Sections, which move from Eaſt to Weſt, and make a Revolution in 19 Years, or thereabouts.

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* 11 Converſ. *ſupra.*

This being granted; no Eclipſe of the Sun ought to happen, with reſpect to us, but when the Moon is between us and the Sun. *Mercury* and *Venus*, which are the only Planets beſide the Moon, that can paſs between the Sun and us, can only hide a part of him from us, which is imperceptible, or almoſt ſo to the naked Eye. Now the Moon can ſcarcely occur between us and the Sun more than two or three times in a Year. For ſhe cannot be in ſuch a Poſition, but when ſhe is with the Sun, and under the Sun, in one of the Nodes, or very near. In every other Situation ſhe has too much Latitude, is too far diſtant from the Ecliptick, and conſequently from the Sun, which never comes out of it, to be between this Luminary and our Eyes; and the Moon is only with the Sun in the Nodes twice every Year, ſince the Sun, which employs a Year in running over the Ecliptick, during all this time is only once in the Point (*a*) of this Circle, and once in the Point oppoſite (*b*). The Moon cuts the Ecliptick twice every Month; for it makes a Revolution in the *Zodiack* in a Month; but the Sun occurs only once in a Year in each of the Sections, or twice in the Nodes. Therefore inſtead of ſeeing Eclipſes of the Sun at every New Moon, they ought ſcarcely to happen twice or thrice a Year.

Eudox.

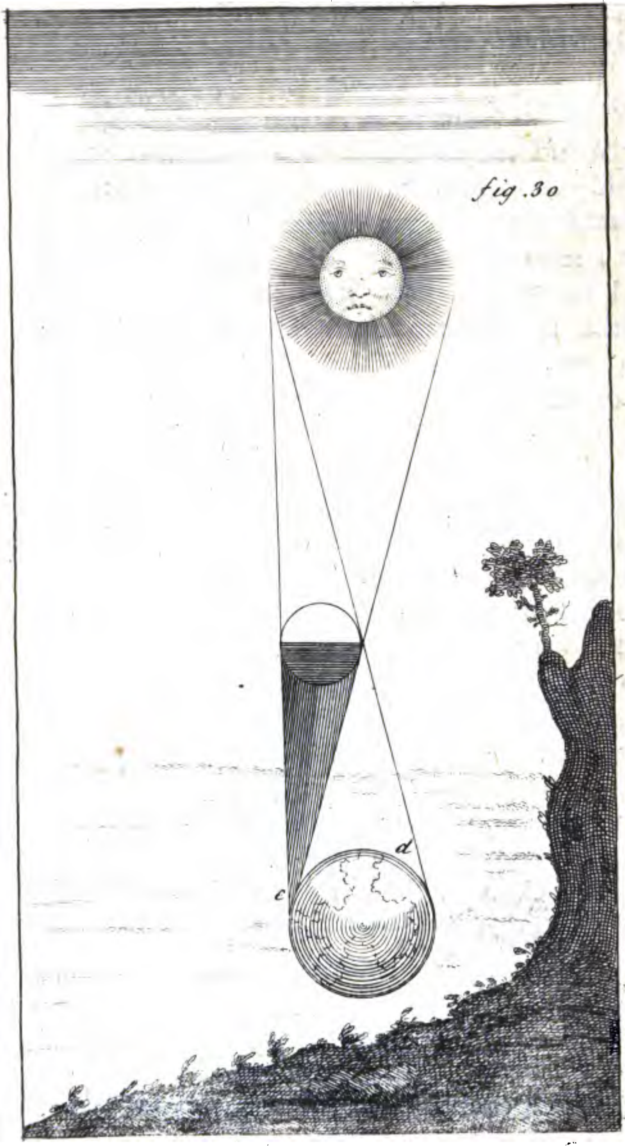
fig. 30
c
d

Eudox. At leaſt the Sun ought, I think, to be eclipſed every ſix Months with reſpect to us, ſince every ſix Months, or thereabouts, he paſſes thro' one of the Points or Nodes in which the Moon cuts the Ecliptick, and in which conſequently the Moon ought to be between the Sun and us.

Ariſt. The Sun ought not to be eclipſed with reſpect to us, but when our Eye, the Moon and Sun are in the ſame Line, in the ſame viſual Ray. Now our Eye, the Moon and Sun do not occur every ſix Months in the ſame Line, in the ſame viſual Ray. Sometimes the Sun reaches the Node ſooner than the Moon, or the Moon ſooner than the Sun; and as the Nodes are changeable, the Sun and Moon, even when they encounter one another therein, are not always in the ſame Situation with reſpect to us; the Sun is hid in them from other Countrys (*c*), without being with-held from our Eyes (*d*), Fig.29. Therefore we ought not to ſee Eclipſes of the Sun every ſix Months.

Eudox. Do you ſee, *Ariſtus*, upon the ſame Principles, the beginning and end of ſolar Eclipſes?

Ariſt. Solar Eclipſes begin at the weſtern Limb of the Sun, at leaſt ordinarily, and end at the eaſtern. Becauſe the Moon going more ſwiftly than the Sun, from the Weſt toward the Eaſt, ſince ſhe compleats her Revolution in leſs than a Month, her oriental Limb begins with joining and hiding from us the Sun's occidental Limb, and only leaves him at the oriental Limb, ſo as to reſtore him entire to our view.

Eudox. But the Buſineſs is to explain, on the ſame Principles, the Differences of the ſolar Eclipſes.

Ariſt. Some are partial, others total; ſome central, others annular [a]. An Eclipſe is partial, when the eclipſed Luminary does not wholly diſappear, or when it preſerves a part of its Light, with reſpect to thoſe who ſee the Eclipſe. It is total, when it wholly diſappears, or when the apparent Disk is wholly covered with Shadow. The Eclipſe is central, when the Center of the eclipſed Luminary, the Center of the Body which eclipſes, the Axis of the Shadow, and the Eye of the Obſervator, are found in the ſame right Line. Laſtly, the Eclipſe is annular [b], when the Circumference of the eclipſed Luminary remains uncovered, and makes a luminous Circle ſhine round the Body which hides it, as has been often obſerved.

In order to comprehend theſe Differences, I obſerve, in the firſt place, that according to the Principles of Opticks [c], the apparent bigneſs of the Disk of the Moon and Sun anſwers to their Diſtances from the Earth; that it is greater toward their Perigeon than their Apogeon; that the apparent Disk of the Moon is ſometimes leſs, ſometimes bigger than that of the Sun[d]; and that the bigneſs of the ſolar Eclipſe depends upon the apparent bigneſs both of the Moon and Sun. In a word, 1. If the Moon, which ought to cauſe an Eclipſe, were ſo little, or ſo far diſtant from us, that ſhe could not be diſcerned, ſhe would cauſe no Eclipſe. *Mercury* may paſs as he pleaſes below the Sun, he does not in the leaſt eclipſe him to the naked Eye. 2. Whenever one of the Extremites of the apparent Diameter of the Sun, is join'd by one Extremity of the apparent Diameter of the Moon, which paſſes under the Sun from Weſt to Eaſt, the Eclipſe begins, as we have ſaid; and it ends exactly when the two Diameters are diſengaged from one another.

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[a] Ric. Almag. T. 1. l. 5. c. 16. p. 231.

[b] Cleomedes l. 2. Cyclicæ Theoriæ, c. 4. Clavius 1567. c. 4. in Sphæram. Jeſſenius 1598. Lansbergius 1601. Le P. Taquet. Aſtron. l. 8. Tract. 3. n. 3.

[c] 20 Converſ. Vol. 2.

This being granted; 1. If the apparent Disk of the Moon, which happens to be under the Sun, is leſs than the apparent Disk of the Sun, it does not hide it wholly from our Eyes; and the Eclipſe is partial. 2. But are the apparent Diameters or Disks of the Moon and Sun, perfectly equal with reſpect to us, ſo that the whole Diameter of the Moon is between us and the Sun? The Eclipſe is total, and for one inſtant only; ſince in that caſe the Diameter of the Moon, which advances continually ſwifter than the Sun from Weſt to Eaſt, entirely hides the Diameter of this Planet, but for a ſingle inſtant. 3. If the apparent Disk of the Moon is greater than that of the Sun, the Eclipſe is more than total, if I may ſo ſay; and the Sun remains ſome Moments wholly conceal'd. Some Moments are required, that the Extremity of the occidental Limb of the Moon may permit us to ſee the occidental Limb of the Sun, in advancing toward the Eaſt. 4. If the apparent Diameter of the Sun is a little larger, and the Exceſs extends every way, the Eclipſe is annular [e]. There remains a Circumference in the Sun, which is not covered, and which by its Splendour makes an obſcure Border or Disk of the Moon; becauſe the obſcure Disk of the Moon is not large enough to hide the Sun's Circumference from the Sight.

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[d] Hiſt. de l'Acad. 1706. p. 115.

Every central Eclipſe of the Sun is total or annular. For in that caſe the apparent Disk of the Sun is larger than that of the Moon, or not; if it is larger, the Eclipſe is annular, ſince it advances equally on all ſides. If it is not larger, the Eclipſe is total, ſince it is entirely hid by a Disk either larger, or at leaſt equal. But if the Eclipſe is total or annular, it does not thence follow that it is central; neither is it neceſſary that the Center of the Sun, the Center of the Moon, and the Place of Obſervation ſhould meet in the ſame Line.

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[e] Le P. Riccioli Almag. nov. T. 1. p. 199. l. 4. de Lunâ, c. 6.

Without this, the Exceſs of the apparent Disk of the Moon may cover the whole Sun, and the Exceſs of the apparent Disk of the Sun may advance on all ſides.

Eudox. But in what particular Situation of the Moon and Sun is the Eclipſe total or annular?

Ariſt. If the Sun is in his Apogeon, and the Moon in her Perigeon, directly between the Sun and the Obſervator, it is natural that the Eclipſe be total, ſince in that caſe the apparent Diameter of the Moon is larger, and the apparent Diameter of the Sun leſs. If the Sun is in his Perigeon, and the Moon in her Apogeon directly between the Sun and Spectator, the Eclipſe ought naturally to be annular, ſince then the apparent Diameter of the Moon is leſs, and that of the Sun larger.

Eudox. One quickly conceives the Appearances of a total or annular Eclipſe. But in 1706, the 21 *May*[f], and 1724, the 22 *May*[g], they had two ſolar Eclipſes total in divers Parts, and more than total, ſince they remained total for ſome time; the ſecond for the ſpace of 2 ¼ Minutes; I myſelf obſerv'd it. In thoſe Eclipſes there appear'd round the Moon a Garland of pale Light, which ſtill grew weaker and weaker without their being properly annular; the Circumference of the

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[f] Hiſt. de l'Acad. 1706. p. 117.

[g] Ibid. 1714. p. 87.

Sun's Disk was not uncovered, the Splendour of the Garland was much leſs than that of the ſmalleſt part of the Sun. Whence can this luminous Garland proceed?

Ariſt. In 1683 [h], M. *Caſſini* diſcovered a Light which follows the Sun, always extended upon the *Zodiack*, and which only appears when the Sun is below the Horizon, always obſcur'd by the Light of the Moon, and without that almoſt continually by the Twilights, which do not permit it to appear but when they are very ſhort. This Light may be cauſed by ſome Matter which iſſues out of the Poles of the Sun, like the magnetic Vortex from the Poles of the Earth and Loadſtone, or out of the whole Globe of the Sun, like Exhalations from the Earth; and, as M. *Caſſini* ſeems to have ſuppoſed after eleven Years Obſervations *, diffuſed in form of an Atmoſphere round the Sun to a certain Diſtance, proportionally thicker as it is nearer this Luminary, and capable of reflecting its Rays towards us, when they cannot come any longer directly to us. Now, is it not probable enough, that the luminous Garland, which has been obſerved in total Eclipſes, is only a Light reflected by this Species of Atmoſphere, with which the Sun is environed?

Eudox. However that be, you will not, I gueſs, imagine to yourſelf, that a total Eclipſe of the Sun may be univerſal.

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[h] Découv. de la Lum. Cel. &c. p. 3. Rec. d'Obſerv.

* Ibid. p. 68.

Ariſt. That an Eclipſe of the Sun might be univerſal, the Shadow of the Moon muſt cover the whole Earth. But the Shadow of the Moon does not cover the whole Earth. This Shadow anſwers to the apparent Diameters of the Moon and Sun; and a Shadow of this ſort cannot cover the whole Earth; for the apparent Diameter of the Sun is ſcarcely larger or ſmaller than that of the Moon, and the Diameter of the Moon is four times ſmaller than that of the Earth. Hence the Eclipſe, which was total in *England* the 31 *May* 1715, was only of 11 $\frac{1}{4}$ Digits at *Paris*[i].

Eudox. During the Eclipſe, the Shadow of the Moon is ſucceſſively ſpread over different Countries of the Earth, with more rapidity than a Cannon-Bullet in the Air[k]. Would you believe it?

Ariſt. While the Moon runs through one degree of its Orbit, the Shadow of the Moon paſſes over a ſpace equal to this degree upon the Earth. Now, in order to run over this ſpace, a Motion is required more rapid than that of a Cannon-Bullet in the Air. For a Velocity of 12 degrees in a Minute, or thereabouts, is required. In ſhort, let us apply one degree of the Moon's Orbit upon the Circumference of the Earth; what proportion has this degree to a degree of the Earth's Circumference? The Circumferences of two Circles are as two Rays; the greater Length the Rays have, the more they diverge; the more the Rays diverge, the greater are the Arcs of the Circumferences contained between the Rays. The Ray of the Moon's Orbit is about 60 times as much as that of a great Circle of the Earth; ſince the Semidiameter of the Moon's Orbit, or the Moon's Diſtance from the Earth is about 60 Semidiameters of the Earth. Therefore the Moon's Orbit is about 60 times as much as the Circumference of the Earth; therefore a Degree of the Moon's Orbit is equal to about 60 Degrees of the Earth's Circumference; therefore it is equivalent to about 1500 Leagues: for a Degree of a great terreſtrial Circle is equal to 25 Leagues, and 60 Degrees multiplied by 25 Leagues afford 1500 Leagues. But the Moon runs through one Degree of her Orbit in about two Hours, ſince ſhe runs through 13 every day. Therefore, her Shadow in two Hours, or in the ſpace of 120 Minutes, runs over about 60 Degrees upon the Earth, and conſequently about 1500 Leagues. It has therefore a Velocity of almoſt 12 Leagues in a Minute; for 120 Minutes multiplied by 12 Leagues, or 120 times 12 Leagues make almoſt 1500. Now a Cannon-Ball has only a Velocity of about three Leagues in a Minute, as we learn from Experience; therefore the

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[i] Hiſt. de l'Acad. 1724. p. 87.

[k] Ibid. 1706. p. 166.

Motion of the Moon's Shadow upon the Earth is more rapid than that of a Cannon-Ball in the Air.

Eudox. Laſtly, when after a total Eclipſe the Sun begins to appear again, the firſt ſmall Portion of the Sun, which diſcovers itſelf, darts out a ſudden and very lively Splendour [l], which ſeems to diſſipate the whole Obſcurity, as I myſelf have obſerved.

Ariſt. When the Sun diſcovers himſelf, the Pupil receives at firſt ſo many more Rays, the more it has been enlarged in the Shadow of the Eclipſe; ſince the Pupil, which is contracted in the full Light, is dilated in the Dark, as we have before ſaid, and for Reaſons which we have mentioned in the Opticks [m]; and the Retina is ſo much the more ſenſible of the ſudden Rays, the leſs its Fibres were agitated. Hence probably proceeds the Vivacity of the Light, the moment it begins to appear, after a total Eclipſe of the Sun.

Eudox. Let us paſs, *Ariſtus*, to the Eclipſes of the Moon. I ſhall ſhew the Appearances and Circumſtances of them. The Remembrance of the Eclipſe which appear'd lately [n], will bring them to mind, and I ſhall have the pleaſure of ſeeing you unravel the Reaſons of them.

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[l] Hiſt. de l'Acad. 1724. p. 87.

[m] 20 Converſ. Vol. 2.

[n] 13 Fevrier 1729.

CONVERSATION XIX.

Upon the Eclipſes of the MOON.

Eudox. WELL, *Ariſtus,* what is an Eclipſe of the Moon?

Ariſt. It is the want of Light, cauſed upon the Surface of the Moon (*a*) Fig. 31. by the Interpoſition of the Earth (*b*) with its Atmoſphere between the Moon and the Sun (*c*). As the Sun and Moon have unequal Motions, and the Moon cuts the Eclip-tick, in which the Sun always is, in two Points, theſe two Luminaries ſometimes meet together in the Nodes or two oppoſite Points, while the Earth is in the middle, in a Line drawn from the Sun to the Moon. In that caſe, the Earth with its Atmoſphere interrupts the Sun's Rays, hinders them from enlightening the Moon, as before; and this is an Eclipſe of the Moon. In ſhort, theſe kinds of Eclipſes do not happen but at the full Moon, that is, when the Earth is between the Moon and Sun.

Eudox. The Shadow of the Earth is Conic, it is an obſcure Cone (*d e f*) of which the Earth is the Baſe, and contained between the Rays which come from the Limbs of the Sun, con-

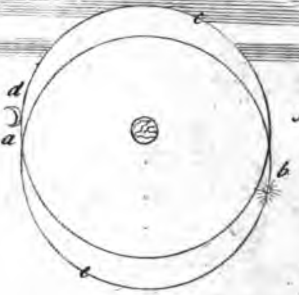

fig. 32.

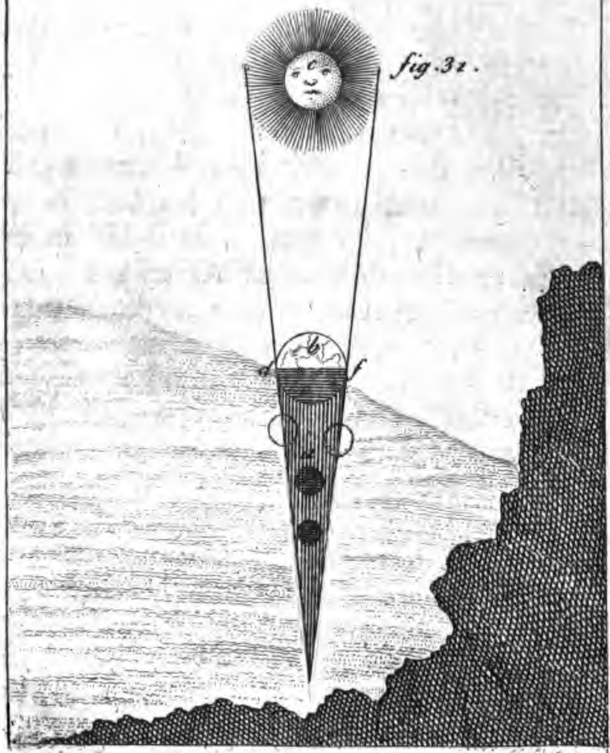

fig. 31.

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continually approaching one another, to graze upon the Limbs of the terreſtrial Globe, leſs than the Sun. How does this conical Shadow convey obſcurity ſo far as the Surface of the Moon?

Ariſt. If the Shadow of the Earth, though conical, extends far beyond the Moon, it is not aſtoniſhing that it eclipſes the Moon itſelf. Now the Shadow of the Earth, extends far beyond the Moon. Father *Riccioli* gives to this Shadow the length of about 213 Semidiameters of the Earth[a]. According to M. *Maraldi's* Experiments in Opticks, the Shadow of a Globe expoſed in full Sun-ſhine terminates at about 110 Diameters of the Globe.[b]; therefore the Length of the Earth's Shadow is about 110 Diameters of the Earth, that is, 330 thouſand Leagues; and the Diſtance of the Moon from the Earth is only 90 or 100 thouſand Leagues at moſt; ſince its leaſt Diſtance from the Earth is about 53 or 54 Semi-diameters of the Earth, its mean diſtance 58, and its greateſt diſtance 62. Therefore, the Shadow of the Earth, altho' it is conical, ought to eclipſe the Moon.

Eudox. Nevertheleſs the Eclipſes of the Moon are not always obſerved, when the Moon is full.

Ariſt. They ought not to happen but when the Moon and Sun are in the oppoſite Nodes, or near to them, ſo that the Earth is directly between thoſe two Luminaries. Theſe Circumſtances are neceſſary, in order to the Earth's hindering the Rays of the Sun from ſpreading themſelves upon the Surface of the Moon. But theſe Circumſtances do not happen in all full Moons; ſince the Sun (*s*) in his annual Revolution only paſſes twice thro' the Nodes of the Moon; that is, thro' the Points (*a, b*), in which the Orbit (*c*) of the Moon (*d*) cuts the Ecliptick (*e*) Fig. 32.

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[a] Almag. l. 5. c. 4. p. 294. n. 3.

[b] Mem. de l'Acad. 1723. p. 13. 118.

Eudox. Sometimes alſo, there is no Eclipſe of the Moon in a whole Year.

Ariſt. If during a whole Year the Moon and Sun are not found at the ſame time in the Moon's Nodes diametrically oppoſite; it is not ſurprizing that a Year paſſes without an Eclipſe of the Moon. But it may happen that during a whole Year the Moon and Sun never meet in the Nodes at the ſame time. For when the Sun by his Motion from the Weſt toward the Eaſt arrives at one of the Nodes, it may be that the Moon, which ought to cut the Ecliptick in the other, has not as yet reached it, or has already paſt it. Therefore in a whole Year there may be no Eclipſe of the Moon.

Eudox. When there happens one, it begins by the Eaſtern Limb of this Luminary *.

Ariſt. The Eclipſe of the Moon ought to begin by that Limb which firſt plunges into the ſhadow of the Earth. The Eaſtern Limb of the Moon is firſt plunged into that, ſince the Moon's

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* Ric. Almag. l. 5. p. 294. n. 3.

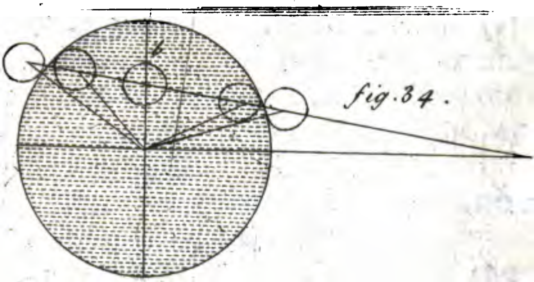

fig. 34.

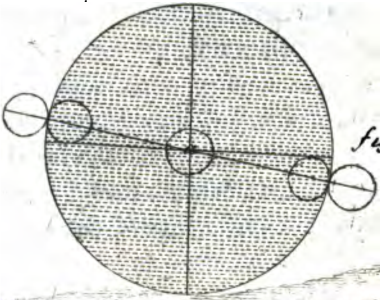

fig. 33.

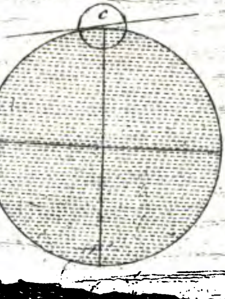

fig. 35.

Moon's Immerſion happens by her moving from the Weſt toward the Eaſt. This Motion alone makes her paſs thro' the Node diametrically oppoſite to the Sun. Therefore the Eclipſe of the Moon ought to begin by the eaſtern Limb.

Eudox. Sometimes the Eclipſe is central (*a*), Fig. 33. ſometimes total without being central (*b*), Fig. 34. ſometimes partial (*c*), Fig. 35.

Ariſt. Sometimes the Moon cuts the Ecliptick in the Node, ſometimes more or leſs near the Node, diametrically oppoſite to the Sun.

When the Moon is in the Node (*a*), Fig. 33. diametrically oppoſite, and her Center in the Line, which paſſes through the Center of the Earth and Sun; the Center of the Moon is in the Axis of the terreſtrial Shadow, and the Eclipſe is central. When the Moon (*b*), Fig. 34. is near the Node, wholly plunged into the Shadow, but without her Center being in the Axis of the Shadow, which ſurrounds her, the Eclipſe is total without being central. When the Moon paſſes at a certain Diſtance from the Node, or from the Line, which runs through the oppoſite Nodes, the Center of the Sun, and the Center of the Earth, the Globe of the Moon (*c*), Fig. 35. is not wholly plunged into the Shadow of the Earth, and the Eclipſe is partial.

Eudox. Even when the Eclipſe of the Moon is total, the Moon ſcarcely ever diſappears intirely *, ſhe almoſt always appears more or leſs reddiſh; much after the ſame manner as we ſaw her lately in a total Eclipſe, the 13th of *February* †.

Ariſt. To explain my Sentiment upon this Head, I ſhall diſtinguiſh with the Aſtronomers two ſorts of Shadows, one a true Shadow, and another which they call Penumbra. Does a Place receive no ſenſible Rays of Light? This is a true Shadow. If it receive ſome ſenſible Rays, it is a Penumbra ‖. This being granted; if even then when the Eclipſe is total, the Moon happens to be in a Penumbra, ſhe ought naturally to be viſible, and appear reddiſh. But the Moon, even then when the Eclipſe is total, is in a Penumbra. For according to the Experiments of M. *Maraldi*, when a Globe is expoſed in the full Sun-ſhine, the true Shadow does not extend above 15 or 16 Diameters of the Globe ‡, the reſt is a Penumbra. Probably many Rays which graze upon the Borders of the Globe, being more compreſs'd upon the ſide which is illuminated, than upon the part of the Shadow, follow the Circumference of the Globe throughout ſome ſmall Extenſion, much after the ſame manner as

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* Hiſt. de l'Acad. 1724. p. 90.

† 1729.

‖ Riccioli Almag. nov. T. 1. l. 5. c. 5.

‡ Memoir. de l'Acad. 1723. p. 118, 119.

Water, which encounters the Piers of a Bridge, and take a direction in order to their proceeding to be re-united at ſome diſtance in the Shadow, ſtill narrower, *&c.* to render themſelves perceptible therein, or to render it leſs dark. Therefore the true Shadow of the Earth projects itſelf but about 15 or 16 terreſtrial Diameters, that is about 45 or 48 thouſand Leagues. The Moon is about 45 thouſand Leagues farther diſtant, and the reſt of the Shadow is a Penumbra. Therefore the Moon eclipſed is in a Penumbra, and that ſo much the brighter, because the Rays, which paſs through the Atmoſphere, proceed from all Parts with different Directions, cauſed by Refractions, to augment its Splendour. Therefore the Moon herſelf in a total Eclipſe ought to be viſible, as ſhe is[c].

Eudox. But according to the Experiments of M. *Maraldi*, the Penumbra of opaque and round Bodies is ſurrounded with a Ring of a true Shadow[d]. Probably becauſe the Rays turned aſide to produce the Penumbra, are not ſucceeded by others. This being granted; in the beginning, and at the end of an Eclipſe, the Borders of the Moon ought to be more obſcure, ſince they would be in a true Shadow; and on the contrary they are thereby more luminous.

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[c] Scheiner. Riccioli. T. 1. l. 5. c. 5. p. 306.

[d] Mem. de l'Acad. 1723. p. 111, *&c.*

Ariſt. May not the Rays, which paſs thro' the terreſtrial Atmoſphere, diſſipate this annular Shadow, and make a luminous Shadow to be ſeen upon the Limbs of the Moon. In ſhort, the Limbs of the Moon ought to anſwer to the Extremities of the Atmoſphere; and theſe Extremities being compoſed of Air not ſo groſs, and of Vapours not ſo condens'd, permit a greater number of Rays to paſs, which are diffuſed upon the Limbs of the Moon.

Eudox. The Moon intirely eclipſed appears ſometimes brighter, ſometimes more obſcure.

Ariſt. That is, becauſe ſhe is immerſed ſometimes more, ſometimes leſs into the Penumbra, and anſwers to the Parts of the Atmoſphere of unequal Denſity.

Eudox. We ſee the Moon in an Eclipſe, ſucceſſively aſſume different Colours.

Ariſt. The Atmoſphere being unequally charged with Vapours and Exhalations, or charged with different Vapours, and different Exhalations in divers Parts, the Rays which paſs entirely thorough it, ſince it is no where impenetrable to the Light, and come to fall upon the Moon, are ſometimes more, ſometimes leſs abundant; ſome of them more, ſome leſs broken; more or leſs ſeparated, more or leſs directed by Refraction toward the Axis of the Shadow, and of the Penumbra.

Now, theſe Differences are ſo many Sources of different Colours [*].

Eudox. In the ſame Eclipſe, the Moon being ſeen from different Parts at the ſame time, ſeems to have different degrees of Obſcurity, different Colours, as happened in the Eclipſe of the 23d *December* 1703, obſerved at *Arles*, *Avignon*, and *Marſeilles* [†].

Ariſt. It is probable, that different Exhalations or Vapours, which do not ceaſe to be unequally diffuſed in the Atmoſphere, altho' the Seaſon be very fair, cauſe thoſe different Appearances in divers Parts at the ſame time. In ſhort, thoſe different Exhalations, and Vapours, are like Glaſſes unequally thick, and diverſely dyed, thorough which the ſame Object appears different.

Eudox. But how comes it that during the Eclipſe, the Moon ſometimes diſappears in a clear and ſerene Heaven [•], before the time of ſetting, before the Twilight can make her diſappear? How comes it, that being in a Penumbra, ſhe diſappears with reſpect to one place, without diſappearing in regard of another, or that ſhe diſappears with reſpect to them at different times, as happened in the Eclipſe of the 23d of *December* 1703?

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[*] Riccioli, T. 1. l.4. c.6. p. 202. n. 12. l.5. c.5. p. 308. Taquet. Aſtron. l. 8. Tract. 3. n. 3. S. 3. Hiſt. de l'Acad. 1704. p. 61.

[†] Hiſt. de l'Acad. 1704. p. 59.

[•] Riccioli, T. 1. l.5. c.5. p. 305. n. 13. l.4. p. 202. Schein. in Diſquiſ. n. 26. Hiſt. de l'Acad. 1704. p. 59.

Ariſt. Probably, becauſe in theſe Circumſtances the interpoſed Vapours ſtopping or breaking the direct or reflected Rays, after an extraordinary manner, only leave the Moon, with reſpect to thoſe who loſe ſight of her, the Colours of the liquid Ground which bears her.

Eudox. According to the Sentiment of Father *Riccioli* [f], if the Moon be beyond the place (*a*), where the Rays broken by the Atmoſphere, croſs one another, and in the true Shadow of the Atmoſphere, Fig. 36. ſhe muſt in that caſe diſappear. However that be, the Duration of the Eclipſes of the Moon is ordinarily greater than that of the Eclipſes of the Sun.

Ariſt. The Duration of the Eclipſes of the Moon depends upon the Diameter of the Earth, which cauſes them. By the ſame reaſon, the Duration of ſolar Eclipſes depends upon the Diameter of the Moon. Now the Diameter of the Sun is much greater than that of the Moon. The Diameter of the Moon is about 800 Leagues, and that of the Earth about 3000: whence the Duration of the Eclipſes of the Moon, is ordinarily greater than thoſe of the Eclipſes of the Sun.

By the ſame Principle, the Eclipſes of the Moon are more frequent than ſolar Eclipſes. As the Diameter of the Earth is much greater than that of the Moon, the Earth ought oftner to

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[f] Almag. T. 1. l. 5. c. 5. p. 305.

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p. 278.

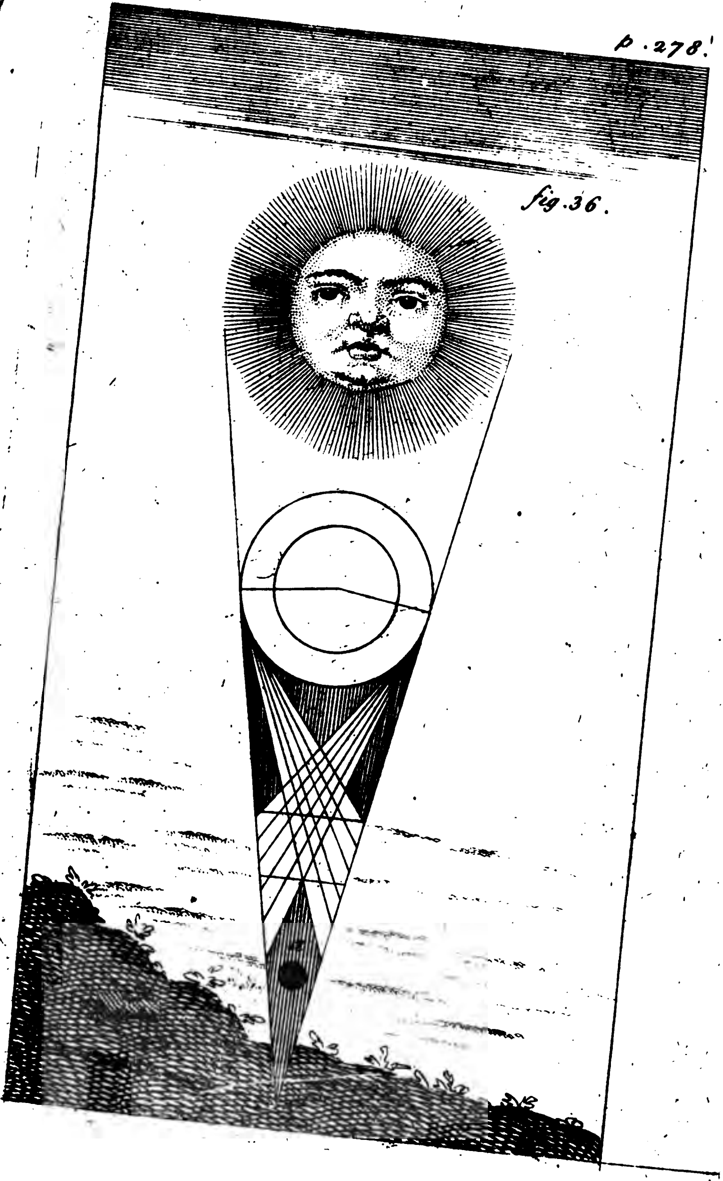

fig. 36.

to hide the Sun from the Moon, than the Moon to hide the Sun from the Earth.

Eudox. Eclipſes of the Moon are ſometimes of two Hours, ſometimes three, and the longeſt about four. The longeſt are central Eclipſes, which happen when the Sun and Moon are in their Apogea.

Ariſt. When the Moon has leſs velocity, and has her Center in the Axis of a larger Shadow, the Duration of the Eclipſe ought to be longer. But when the Eclipſe is central, and the Sun and Moon are in their Apogea, the Moon has leſs velocity, becauſe ſhe is farther diſtant from the Center of her Vortex. She has her Center in the Axis of the Shadow, ſince we ſuppoſe the Eclipſe central; and the Shadow is larger, for the Diameter of the Shadow is ſo much the larger, the farther diſtant the Sun is from the Earth. In ſhort, if we bring a luminous Body near a Ball, greater than the Ball itſelf, the Shadow of it is conical and leſs. The more we remove the luminous Body from the Ball, the more the Diameter of the Shadow increaſes. The Shadow augments proportionally as the Rays, which come from the Extremities of the Sun to graze upon the Earth, approach nearer to two parallel Lines; and the farther diſtant the Sun is, the more they approach to two parallel Lines; and the more the Angle which they make diminiſhes. Therefore the longeſt Eclipſes of the Moon ought to happen, when they are central, and the Sun and Moon are in their Apogea.

Eudox. But when the Eclipſe happens in the Moon's Perigeon, the Moon is found in a greater Diameter of Shadow, ſince the Shadow of the Moon is conical. Therefore the Eclipſe ought to be of longer Duration.

Ariſt. If the Moon in that caſe runs over a larger Diameter of Shadow, ſhe has more Velocity, being nearer the Center of her Vortex; and this exceſs of Velocity prevails over the exceſs of Diameter.

Eudox. The Eclipſes of the Moon are of uſe for knowing the Longitudes or Diſtances, both northern and weſtern.

Ariſt. The Moon being eclipſed, loſes her Light in effect, ſince ſhe has no proper Light, Wherefore the Eclipſe begins and ends at the ſame time, with reſpect to the whole Hemiſphere, which ſees the Surface of the Moon. This being granted, whenever I know what Hour it was in an eaſtern or weſtern Part when the Eclipſe began to appear, I know the Diſtance from our Meridian, to that Place. For example, was it mid-night in any eaſtern Place, and only ten at night here? The Sun is two Hours ſooner in the Meridian of that Country than in ours; he comes from thence to us in two Hours. Now in two Hours the Sun runs over 30 degrees of the Earth, ſince in 24 Hours he runs over 360. Therefore the Longitude of the eaſtern Place, which we ſpeak

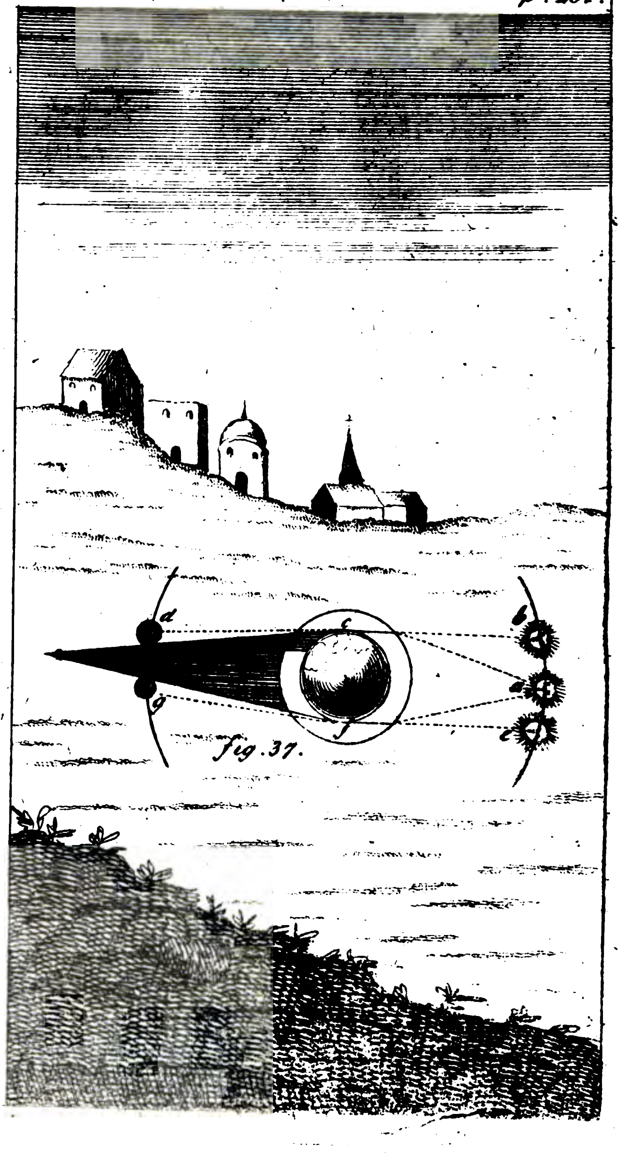

fig. 37.

NIV. OF CH.

ſpeak of, or its Diſtance from our Meridian, is 30 degrees. I multiply the Leagues of one terreſtrial degree by 30, and the Product is the Longitude, which I was ſeeking.

Eudox. A very rare Event, and which ſeems to overturn your Principles, is, that the Moon is eclips'd ſometimes in the Sun's Preſence, when theſe two Luminaries appear near the Horizon [g]. Theſe horizontal Eclipſes have been ſeen in divers Ages. They had ſeen of them at leaſt in the time of *Pliny* [h]. They ſaw another the 17th of *July* 1590, at *Tubinge* [i]. A third was ſeen at *Taraſcon* the 30th of *November* 1648. And a fourth in the Iſland of *Gorgone*, the 16th of *June* 1666 [k].

Ariſt. The Moon and Sun are not in that caſe both actually above the Horizon, but the Refraction which elevates Objects, as we have ſaid [l], elevating thoſe Luminaries, at leaſt one of them, namely the Sun (*a*), Fig. 37. more than they are really elevated, makes them both to appear at the ſame time above the Horizon (*b c d*). By the ſame Principles, thoſe who are above the inferiour Horizon (*e f g*), may ſee them there at the ſame time.

Eudox. Finally, the Eclipſes of the other Planets, of the Satellites, and of the fixt Stars, happen according to the ſame Principles; and the Knowledge of the Difference of the times when theſe Eclipſes, eſpecially thoſe of the Satellites of *Jupiter*, which happen very often, are ſeen from divers Parts, makes us know the Difference or Diſtance of Meridians, and conſequently the Longitudes of divers Climates. If two Obſervators ſee the ſame Emerſion of the fourth Satellite of *Jupiter*; ſuppoſe from two different Places they ſee this Satellite come out of the Shadow of its primary Planet; ſuppoſe it be mid-night in one of theſe Places, and two Hours after mid-night in the other: this will be more eaſterly by 30 degrees.

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[g] Mem. de l'Acad. 1711. p. 234.

[h] Pliny, T. 1. l. 2. c. 24.

[i] Kepl. Aſtron. Opt. p. 136. Riccioli, T. 1. l. 5. c. 5. p. 307.

[k] De l'Eclip. horiz. de Lune 16 Juin 1666. J. des Sçav. p. 426.

[l] 20 Converſ. Vol. 2.

Comets are celeſtial Bodies, which more ſeldom appear. Accordingly they are probably leſs known.

Ariſt. You will favour me upon this Head with what ſeems moſt probable to you; and I ſhall be ſatisfied.

Conversation XX.

Upon Comets.

Ariſt. PRAY, *Eudoxus*, what are the Appearances of Comets? What Reality is there in thoſe Phænomena? What are the Cauſes of their Appearances? Have People reaſon to be alarm'd at the ſight of a Comet, notwithſtanding the Diſcourſes of Philoſophers?

Eudox. They obſerve in the Heaven from time to time new Stars, as it were, or rather new Planets, ſurrounded with a ſort of Atmoſphere, ſometimes leſs, ſometimes more bright, ſometimes ſmaller, ſometimes greater, carried towards divers Points of the Heavens, with Differences of Velocity and Elevation; and this is what they call Comets*. Father *Riccioli*

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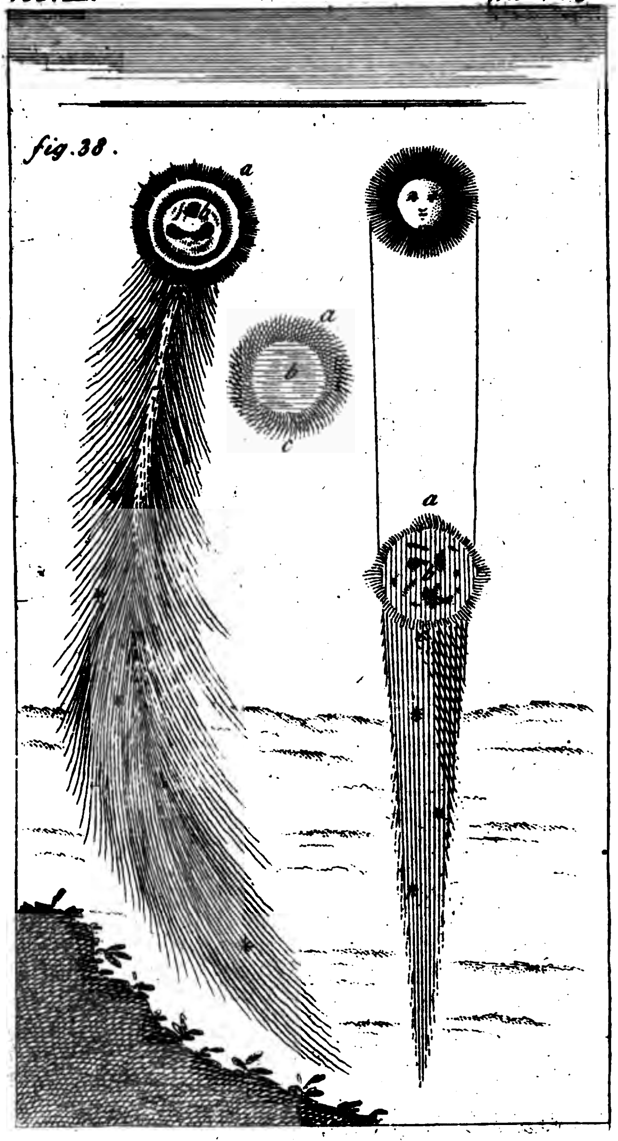
* The Comets ſeem to be the moſt extraordinary Appearances in Nature, and to have been as yet leaſt accounted for; having been thought very irregular, and ſubject to no certain Laws. But from later Obſervations, and more ſtrict Enquiry, even *Thoſe* alſo are found to move in very regular Curves, and to be ſituated in the beſt Poſition, with reſpect to each other; and to be of conſiderable uſe. They appear to be very numerous; which

Riccioli talks of 154 Comets obſerved from the Year 480, before the Birth of Jeſus Chriſt, to

which Conſideration alone is ſufficient to ſuggeſt to us, that there muſt be great occaſion for them in ſuch a Syſtem as this. They are a kind of Planets, being large and denſe Bodies, with very groſs Atmoſpheres, and are capable of emitting great quantites of Vapours, as appears from the Bigneſs and Length of their Tails; and they revolve about the Sun in very large Ellipſes, of which the Sun is one of the Focus's. From all which we may collect ſome of their principal Uſes alſo. The Body of the Sun muſt neceſſarily be diminiſhed by that vaſt quantity of Light that is perpetually emitted from it, and therefore in time will decay and ſtand in need of a ſupply of freſh Materials for Fewel. Theſe may be had from Comets: For by Obſervation we find, that they ſometimes approach very near the Body of the Sun, and conſequently muſt at laſt fall into it. For by reaſon of their prodigious Swiftneſs at that Time, and the Denſity of the Sun's Atmoſphere, their Motion muſt be ſomewhat reſiſted and retarded; ſo that they will revolve nearer and nearer till they run into it. This may alſo be promoted by the Gravitation of other Comets, when they are *in Aphelio*; becauſe they move ſloweſt in that part of their Orbit, and conſequently will be retarded by ſuch Attraction, and an Alteration be produced in the Figure of their Orbs. But before they come to this, there are very good reaſons to think that they are of great Benefit to the Planets. Experience ſhews us, that the Water in the Sea continually decreaſes, and the dry Ground continually encreaſes; the great quantity of Vapours which are exhaled from thence, being converted into Nouriſhment for all kind of Vegetables, which when they come to putrify, are in good meaſure turned into dry Earth, ſo that by this means a great part of the Liquid is deſtroyed: All which Defects are probably ſupplied from the Tails of Comets: For theſe conſiſting chiefly of ſuch Vapours, and ſpreading themſelves to an immenſe Diſtance through the heavenly Spaces, may fall by their own Gravity into the Atmoſpheres of the Planets, and there be condenſed, and turned into Water and other Subſtances. To this we may add, that the fineſt and moſt ſpirituous part of our Air, which is the moſt ſubtle, and the beſt, and is neceſſary to preſerve Life in every Thing, may with good reaſon be thought to proceed chiefly from the Comets. And from all theſe things put together, it is manifeſt why the Comets are not, like the Planets, confined to the *Zodiack*, but cut the Ecliptick at all Angles, and move freely

fig. 38.



to the Year 1618 *. Since that time many have been ſeen, namely in 1652, 1665, 1682, 1689, 1699, 1702, 1706, &c.

In a Comet we may diſtinguiſh the Body, the Atmoſphere, the Degree of Light, the Bigneſs, Direction, Latitude, Velocity, and Elevation of the Comet.

When one obſerves a Comet (*a*), Fig. 38. one remarks therein a Light (*b*), more lively than that of the Atmoſphere (*c*), which ſurrounds it, but very ſmall in compariſon of this Atmoſphere †; and this is probably the Body of the Comet.

The Atmoſphere which ſurrounds it in form of Hair, and ſeems ſometimes to follow it in form of a Tail, is a Species of luminous Cloud, ſtill diminiſhing in Splendour towards the Borders [a], and tranſparent even in that part where it is moſt condens'd and thick, ſince one ſees the fixt Stars thorough it [b].

The Light and apparent Bigneſs of Comets are ſometimes like thoſe of a ſmall clouded Star [c], ſometimes like thoſe of *Jupiter*. We have

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freely thro' every part of the Heavens, *viz.* that when they are at the greateſt Diſtance from the Sun, and move moſt ſlowly, they might alſo be at the greateſt Diſtance from each other, and ſo diſturb one another as little as poſſible by their mutual Attraction. *Dr.* John Clarke's *Sermons at* Boyle's *Lect.* Vol. 1. p. 115.

* Almag. l. 8. ſ. 1. c. 3.

† Hiſt. de l'Acad. 1708. p. 104. M. 1707. p. 323. M. 1723. p. 255, 290.

[a] Hiſt. de l'Ac. 1706. p. 104.

[b] Ibid. 1723. M. p. 255, 290.

[c] Ibid. 1706. p. 104.

have ſeen through a Glaſs, ſays M. *Caſſini*, Comets whoſe Diſcus was as big, pure and clear as that of *Jupiter*. Such was the ſecond Comet of 1665, and that of 1682[d]. *Tycho* had ſeen ſome much like them in 1585, and 1590[e]. Sometimes Comets appear like a great Star; ſuch was that which appeared in the Months of *February* and *March* 1702[f], obſerved at the Mouth of a River of *Miſſiſſipi* in *America*, by M. *le Sueur*. *Seneca* ſpeaks of a Comet as big as the Sun[g].

Comets have different Directions in their Motions. Some come from Eaſt to Weſt, as the ſecond of 1702[h]. Others come from North to South, as thoſe of 1689, and 1699; or from South to North, as thoſe of 1472, and 1556[i]. That of 1707 mov'd almoſt directly from South to North, from Pole to Pole; but about the end it returned from North to South, and appear'd to move obliquely from the Weſt toward the Eaſt[k]. Comets, which move from Eaſt to Weſt, are more frequent than thoſe which move from one Pole to another[l].

The Comet of 1706, might be 55 degrees diſtant from the Equator *.

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[d] Mem. de l'Ac. 1699. p. 39.

[e] Taq. Aſtron. l. 8. tr. 2. p. 331.

[f] Hiſt. de l'Acad. p. 67. M. p. 216.

[g] L. 7. Nat. Quæſt. c. 15.

[h] Hiſt. de l'Ac. 1702. p. 67. 1706. p. 104.

[i] Ibid. 1708. p. 100.

[k] Ibid. 1708. p. 98.

[l] Ibid. 1708. p. 101.

* Ibid. 1706. p. 104.

Comets in their different Directions ſeem to deſcribe an Arc of a great Circle, whoſe Plane paſſes thro' the Center of the Earth [m]. While thoſe, which are viſible, run over the Arc of their Circle; we ſee ſeveral of them augment equally from day to day, both in Velocity and apparent Bigneſs, to a certain degree, like Planets which approach their Perigeon; and after that, during an equal time diminiſh equally in Velocity and apparent Bigneſs, like Planets which remove from their Perigeon; and continue and diminiſh after that manner until they diſappear entirely [n]. In 1708, M. *Caſſini* wrote of ſix Comets ſince 1580; which after their firſt Appearance had continually augmented in apparent Velocity and Bigneſs; but in unequal times, the ſhorteſt of which had been ten Days, and the longeſt 43 [o].

There is a Point therefore in which Comets appear biggeſt, and their Motion ſeems to have the greateſt Velocity. Their Motion is equal, or almoſt equal, at equal diſtance from this Point, both on the one ſide, and the other, as was remarked in the Comet of 1698 [p]; and this Point is call'd the Perigeon of the Comet. The Comet of 1723, had the laſt day of its Appearance only a 60th part of the Motion, which it muſt have had in its Perigeon [q].

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[m] Mem. de l'Ac. 1699. p. 36. 1706. M. p. 92.
[n] Ibid. 1724. p. 376.
[o] Hiſt. de l'Ac. 1708. p. 101.
[p] Mem. de l'Ac. 1699. p. 37.

Finally, the Elevation of all Comets is not the ſame, ſince according to the Obſervations of Aſtronomers, ſome of them have a certain Parallax, greater or ſmaller, and others have none at all. They gave ſix degrees of one to a Comet of 1472, which placed it ſix times nearer the Earth than the Moon, ſince the Moon has only about one degree of Parallax. But thoſe ſix degrees do not ſeem very probable. The Comet of the Month of *April* 1702, appear'd to M. *Maraldi* to have an horizontal Parallax of 13 minutes; which gives it a diſtance from the Earth about five times greater than that of the Moon [r]. The Comet of 1707 had only two Seconds of Parallax at moſt [ſ]. That which was obſerved the ſecond of *March*, the ſame Year, had no perceptible Parallax [s]. This being granted; Comets, at leaſt a great number of them, cannot be leſs elevated, or ſcarcely leſs elevated, than *Mars*, the laſt Planet in which they find any Parallax; a Parallax, I ſay, difficult enough to be verified [t]. They are not above the fixt Stars; ſince the fixt Stars are eclips'd by them. The Comet of 1706 hid a Star [u]. M. *Caſſini* places the Comets of 1652, and 1680, between the Circles of *Venus* and *Mars*, above the Parallax which he thought he found in them[v]. Theſe are the Appearances of Comets; what is there of reality in them?

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[q] Mem. de l'Acad. 1723. p. 254.

[r] Hiſt. de l'Acad. 1702. p. 68.

[ſ] Mem. de l'Acad. 1708. p. 330.

[s] Ibid. 1702. p. 102.

[t] Ibid. 1699. p. 39.

[u] Ibid. 1706. p. 91.

Ariſt. I fancy I perceive it in the true Explanation of their Phænomena.

Eudox. Do you believe that they are Exhalations of the Earth kindled in this immenſe Liquid, in which the Luminaries ſwim, fortuitous and fleeting Productions?

Ariſt. That is not probable; why? 1. Sometimes the Exhalations of the Earth would aſcend, at leaſt to the diſtance of 15000 Leagues, as in the Comet of 1472, if it is true that it had ſix degrees of Parallax, ſince the Moon, which has only one, is about 90 or 100 thouſand Leagues diſtant. Sometimes the Exhalations of the Earth would be found at the diſtance of about 500000 Leagues, as in the Comet of the Month of *April* 1702, which appeared to have 13′ of Parallax, or to be five times more elevated than the Moon; ſometimes the Exhalations of the Earth would be elevated to an inconceiveable diſtance; ſeeing there are Comets, which have no Parallax, as the firſt of 1702, and yet *Mars* has one. But it is no way probable that the Exhalations of the Earth are elevated to ſo prodigious a diſtance. Therefore, *&c.* 2.

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[v] Mem. de l'Acad. 1699. p. 72.

2. We ſee Comets, whoſe Diſcus is as round and clear as that of *Jupiter*, ſuch as that of 1681; other Comets, as big as a large Star, and without any Parallax, ſuch as that of *March* 1702. Theſe Comets, in order to appear ſo perceptibly at ſo prodigious a diſtance, ought, I think, to have a Globe as great as that of the Earth at leaſt. Pray, how ſhould the Earth furniſh ſo many Globes of inflammable Matter, as big as itſelf?

Upon the ſame Principles, Comets are not Exhalations that iſſue out of Planets.

3. Finally, we ſee Comets augment at the ſame time, both in velocity and bigneſs, ſometimes during 10 days only, ſometimes during more than 40; and after that, to diminiſh in velocity and bigneſs, in the ſame *ratio*. Now, did this perfect Conformity of theſe apparent Augmentations and Diminutions happen in kindled Exhalations, in fortuitous and fleeting Productions, inflamed ſuddenly, and by chance; the kindled Productions would ſucceſſively increaſe and diminiſh in bigneſs: but for all that, they would neither increaſe nor diminiſh in velocity, as they do. They ought to take the Direction of the Vortex, and yet they often have contrary ones. In being kindled, they would become more rare; being more rare, they would more eaſily obey the Direction of the Fluid, in which they float: and yet oft times the more they appear to be inflamed, and to increaſe in

Splendour and Bigneſs, the more ſwiftly they move againſt the Direction of this Fluid, as the ſecond of 1702. Therefore Comets are not fleeting and inflamed Productions. In ſhort, they ſend forth no Rays, as Bodies ordinarily do which ſhine of themſelves: and would forfuitous and fleeting Flames appear to the Eye three, four, and ſometimes ſix Months?

Eudox. What then are Comets?

Ariſt. It is probable that Comets are ſolid, durable Bodies, as old as the World; Planets, which have only one part of their Courſe or Circle within the reach of our View. For in a word, as we have already prov'd, Comets are not Exhalations, fortuitous and fleeting Fires, ſuddenly kindled in this vaſt Liquid, in which we ſee them. Therefore, *&c*.

Eudox. If Comets are regular Bodies, or whoſe Courſe is regular, as they have only a foreign Light, ſince they do not twinkle, and their Atmoſphere has different Figures, different Aſpects, according to their Situation with reſpect to the Sun, they muſt be ſolid Bodies, Planets. Now, Comets are probably regular Bodies, ſuch whoſe Courſe is regulated; for it is probable, that they have their Returns, or that they appear again after a certain time, a certain number of Years. If we find that a Comet has at one and the ſame time both the ſame Nodes in the Ecliptick, and the ſame Inclination to the Ecliptick, and the ſame degrees of apparent Velocity, which have been obſerved in a Comet ſeen formerly, one may judge with great probability, that this is the ſame Comet. We do not find, ſays M. *Caſſini* [w], that two Planets agree in theſe three principal things. Now all theſe Conformities were found between the Comet of 1577, and that of 1680. They found the ſame relation almoſt between the Comet of 1652, and that of 1698 [x]. Therefore 'tis probable, that Comets are regular Bodies, ſolid Bodies, Planets.

Thus they ſufficiently foreſee the Courſe of a Comet, after having obſerved it two or three times [y], as M. *Caſſini* did, particularly in the Year 1664, and 1681. And if we have been ſeveral Days together without being able to diſcern it, we know to what part of the Heaven the Glaſs muſt be directed, in order to find this Luminary [z]. Since the time of *Ariſtotle* there have been Philoſophers, who have given this kind of Phænomena regular returns [a].

Ariſt. But, *Eudoxus*, our Buſineſs is to reconcile the Appearances of Comets with Phyſicks, upon this Hypotheſis. We ſee Comets augment in the ſame time, both in velocity and apparent bigneſs, and after that to diminiſh

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[w] Mem. de l'Acad. 1699. p.41.

[x] Ibid.

[y] Ibid. 1702. p. 128.

[z] Ibid. 1706. p. 105.

[a] Ibid. 1702. p. 108.

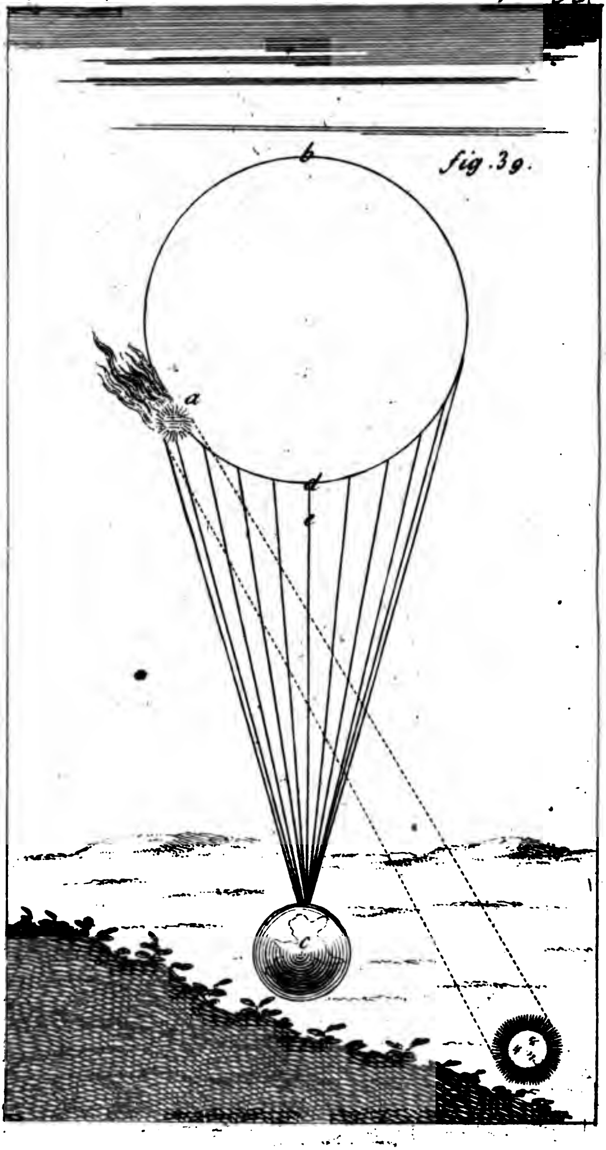

fig.39.

diminiſh in the ſame time, both in bigneſs and velocity. How ſhall we explain this Phænomenon?

Eudox. Let us ſuppoſe, with M. *Caſſini*, that a Comet (*a*) deſcribes a great Circle (*b*), excentrick to the Earth (*c*), ſo that it does not contain it, and whoſe inferiour part, which prolonged, would cut the Center of the Earth, is viſible, while the ſuperiour part proceeds to loſe itſelf in the Heavens. The Point (*d*) of the inferiour part, neareſt the Earth, is the Perigeon of the Comet. Let us now conceive the inferiour part of the Circle divided into equal Arcs. To all theſe Diviſions let us draw right Lines from the Center of the Earth, or from the Eye of the Obſervator. Theſe ſtrait Lines will make unequal Angles, the equal Arcs contained between theſe Lines being unequally inclin'd to theſe Lines, ſome more, and others leſs. The Angles will be ſo much the greater, as they are nearer to the Perigeon (*d*), or to the Perpendicular (*e*) drawn from the Center of the Earth to the Center of the Orbit, Fig. 39. For the Arcs being more parallel to the Horizon, will render thoſe Lines more diverging; and conſequently the Arcs will appear ſo much the greater, the nearer they are to the Perigeon, ſince they will be ſeen under greater Angles.

Ariſt. This being granted; 1. A Comet, which deſcends towards the Perigeon, ought to increaſe in apparent bigneſs, becauſe it approaches to the Earth. 2. A Comet which deſcends ought likewiſe to increaſe in apparent velocity, if proportionally as it deſcends, it deſcribes in equal times Arcs ſenſibly greater: but in equal ſpaces of time it deſcribes Arcs ſenſibly greater; ſince it approaches to the Perigeon, and the Arcs appear ſo much the greater, the nearer they are to the Perigeon. By the ſame Principles, a Comet ought to diminiſh in apparent bigneſs and velocity, proportionally as it removes from the Perigeon, ſince it continually removes from the Earth, in deſcribing Arcs ſenſibly ſmaller in equal ſpaces of time. Therefore this Phænomenon may be reconciled with Phyſicks.

In ſhort, the nearer the Arcs are to the Perigeon, the more diſtinctly are the parts of thoſe Arcs diſcerned, being ſeen by more diſtinct Rays. The farther diſtant the Arcs are from the Perigeon, the leſs diſtinctly are the parts of thoſe Arcs ſeen, becauſe the Arcs becoming ſenſibly, or almoſt ſenſibly perpendicular to the Eye, the Rays which come from every one of their parts to the Eye, penetrate, as it were, one another, and are confounded in ſome meaſure, without making different Impreſſions upon the Retina. Wherefore, when a Comet runs through the Arcs, which are farther diſtant, the Eye does not diſcern at all, or leſs diſcerns its Paſſages from one Point of the Orbit, to another; the nearer the Comet approaches the Perigeon, the better the Eye diſcerns its Paſſages from one Point to another: now, the more we diſcern the Points of the Orbit run through in a certain time, the more velocity the Body ſeems to have, which runs through them; ſince the apparent velocity is meaſured by the ſpace ſenſibly run through. Therefore the Comet ought to encreaſe in apparent velocity and bigneſs as far as the Perigeon, and after that by a contrary reaſon to diminiſh both in apparent velocity and bigneſs.

Eudox. But ſometimes Comets only diminiſh in bigneſs and velocity after their firſt Appearance.

Ariſt. That is, becauſe they have not been perceived before they were in their Perigeon; becauſe the Clouds, Twilights, or Rays of the Sun being too near, hindered them from appearing.

Eudox. At leaſt in the beginning of their firſt Appearance, we ought, I think, ſometimes to ſee in them the ſame bigneſs and velocity, which they have when they ceaſe to be viſible; ſince they are at the ſame diſtance from the Perigeon; and this is what M. *de la Hire* ſays has never been ſeen.

Ariſt. Probably becauſe Comets, by reaſon of Clouds, Twilights, Proximity of the Sun, or Inadvertency of Aſtronomers, have never appear'd the firſt moment that their diſtance permitted their being ſeen.

Eudox. Comets have no Radiation, or Scintillation.

Ariſt. Becauſe they are ſolid Bodies, which have only a borrowed Light, too much weakned by Reflection to ſend forth Rays at ſo great a diſtance.

Eudox. Nevertheleſs the whole Disk of the Comet appears always enlightened.

Ariſt. Becauſe the whole Disk, which faces us, is always enlightened by the Rays of the Sun, on the account of its great Elevation.

Eudox. But why do Comets, or at leaſt ſome of them, appear only two, three, four or ſix Months at moſt, in 30 or 40 Years, ſince they are Planets whoſe whole inferiour Disk faces us at the ſame time it faces the Sun?

Ariſt. 1. Probably becauſe their Circle is immenſe, and they are only viſible in the inferiour part of their Circle. 2. Clouds, Twilights, and their Proximity to the Sun, may often hinder their return from being perceived.

But pray, *Eudoxus*, what can give Comets directions from Pole to Pole, and alſo from Eaſt to Weſt, contrary to the Torrent * of the Vortex, in which the Planets are carried, and force them to follow thoſe Directions?

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* See Notes Converſ. XV. *ſupra*.

Eudox. Currents which iſſue out of other Vortices, or the Impetuoſity of other Vortices, and other Stars, may, I think, give them both thoſe Directions, and force them to follow them, without any ſenſible Diminution of Motion. Beſides, the Satellites of *Jupiter* and *Saturn*, when they are retrograde, or in the inferiour part of their Circles, are carried againſt the Direction of the general Vortex by their particular Forces, or by thoſe of their proper Vortex. May not Comets, by the ſame Principle, ſeem to be carried for ſome time contrary to the Torrent of the Vortex of the Planets? The Impetuoſity which precipitates them into this Fluid, ſerves to preſerve their contrary Direction; after that they aſcend again, meeting with leſs Obſtacle in the ſuperiour part of their Circles. Hence toward the end of their Appearance we ſee them often turn aſide toward the Eaſt. In a word, it is probable that many Comets which have no Parallax, are above *Saturn* itſelf, in irregular Currents, cauſed by the Vicinity of divers Vortices; and thence proceed the different Directions which are obſerved in different Comets.

Ariſt. It naturally follows from our Converſation, that we ought not to be alarm'd at the ſight of Comets, as People were in former times; ſince we have prov'd Comets to be regular Bodies, Planets.

Eudox. “While the Heavens were little obſerved, Comets were rare, ſays M. *de Fontenelle*[b], and only thoſe were ſeen which were very viſible; whoſe bigneſs and figure, joined to their rareneſs, ſtruck a Terrour in all Places. At preſent, while the Eyes of a great number of skilful Aſtronomers are always open to explore all the Corners of the Heavens, Comets become common, and Perſons grow familiar to them, ſo as to call them Planets.” Sir *Iſaac Newton*'s Syſtem ſeems naturally to preſent itſelf, and deſerves ſome Attention.

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[b] Hiſt. de l'Acad. 1702. p. 68.

Conversation XXI.

Upon Sir Isaac Newton's *Syſtem.*

Eudox. TRULY, *Ariſtus*, we have taken too much pains to give to Planets and Comets directions approv'd by Philoſophy. Had we not done better to have begun with annihilating this vaſt Fluid, in which they make the Luminaries ſwim? The Planets would have room enough in an immenſe Vacuum. The Planets and Comets ſuſpended by the Hand of the Creator in the Vacuum, and placed, thoſe in different Circles round the ſame Center, and theſe in excentrick Circles, unequal and differently directed, would peaceably make their Revolutions; no Obſtacle would trouble them, nor diſquiet Philoſophers. Comets needed only to follow their firſt Direction, and wander without any Irregularity, ſome toward the Eaſt or Weſt, and others Northward or Southward.

Ariſt. This Syſtem would be commodious enough; an air of Novelty would recommend it; perhaps it would want nothing but a little more Probability and Truth.

Eudox. Notwithſtanding, this Hypotheſis is true, according to Sir *Iſaac Newton*; and this great Man did not queſtion but that there were imaginary Spaces in the World itſelf *. Neither the ſubtile Matter, nor the etherial Matter, with which M. *Deſcartes* made Heaven and Earth to be over-flowed, could be digeſted by this famous *Engliſhman*; and far from looking upon this fine Matter as the Soul of the World, he thought it only proper to cauſe a general Stagnation in the Univerſe. Thus he gives it no quarter, and concludes with rejecting it entirely.

Ariſt. I ſhould not ſuſpect Sir *Iſaac Newton* to have allowed himſelf to be ſurprized, by a ſecret pleaſure of eſtabliſhing a Syſtem upon the Ruins of a famous Hypotheſis. The Authority of ſo great a Name is to be reſpected; and he deſerves the Honour which *England* did him, and itſelf, by honouring Learning in a learned Man. But Authority, I muſt own, does not ſeem here wholly conſonant with Philoſophy. Allow me to declare my Sentiments upon this Matter.

The Laws of Nature obſerved upon the Earth, ſeem to me to be obſerved in the Heavens, which are within reach of our Senſes. This Uniformity in ſo great a piece of Workmanſhip, is worthy both of the Wiſdom and Simplicity of its Author; it bears the Impreſſion of his Attributes. Hence, we ſee, for example, that which ſpreads Darkneſs and Light over the Earth, alſo ſpreads Light and Darkneſs over the Heaven and Planets. Now upon the Earth, a Body moved circularly, whenever it is at liberty, or is not detain'd by ſome external Matter, deſcribes a right Line, which removes it from the Center of its Motion. A Stone thrown out of a Sling becomes viſible to the Eye; if the Stone preſerved its circular Motion, it would be a prodigious thing, a Miracle. This being granted; here is the Reaſoning which preſents itſelf to my Mind.

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* See Notes Converſ. 5. Vol. 1.

Planets and Comets have always a circular Motion; this is agreed on. But if the Space, in which thoſe Luminaries make their Revolutions, were void, they ought long ago, inſtead of moving circularly, to have deſcribed right Lines towards the Region of the fixt Stars; ſince among Bodies, which are within reach of our Senſes, a Body which moves round, paſſes off by a right Line[*], whenever

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[*] It is now apparent from the moſt exact Obſervations of the Phænomena of the celeſtial Motions, that they are ſo placed in the moſt free and open Spaces, as to revolve about certain Centers, by a Force compounded of *Gravity*, and a *projectile Motion in ſtraight Lines*, which were impreſſed upon them by God at the Beginning; *viz.* the larger Planets about the Sun, and the Satellites or Moons about their own Planets: this may be explained in a few words.

Becauſe all Matter gravitates towards all Matter, in a certain Proportion to the Quantity and Diſtance (*Confer. Notes Converſat.* XV. *Vol.* 1.) And becauſe the Body of the Sun is much larger it is at liberty, or is not ſtopt by the reſiſtance of ſome external matter; the Luminaries ought long ago, at the rate of their Motion, to have wandered among the fix'd Stars, or rather to have ſerved for Nouriſhment to ſome Stars which would have ſwallowed them up.

Eudox. Oh! have a care, *Ariſtus*; the Gravity which gives the Planets a continual tendency toward the Center of their Motion, retains them in their Orbits, and hinders them from going aſide, notwithſtanding the liberty they would be at, of ſo doing in a Vacuum. Therefore Gravity is a wonderful means of

explaining

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than all the Planets put together; it is manifeſt that if all the Planets were at reſt in their proper Places, they would by their own Gravity be carried directly into the Sun.

Now becauſe the Caſe was thus, and all the Planets *gravitated* towards the Sun, God impreſſed upon them a *projectile Motion in ſtreight Lines* alſo; in ſuch a manner as to be perpetually pulled from theſe ſtraight Lines, and kept from flying off from their Orbs by Gravitation, and at the ſame time to be perpetually urged on by that *projectile Motion*, leſt they ſhould fall into the Sun by the force of their Gravitation: ſo that by theſe two Forces acting together, they muſt neceſſarily be carried in ſome curved Line about the Sun; juſt as a Stone turned about in a Sling, by being perpetually hindred by the String from flying off, all the while that it endeavours to recede from the Center by its projectile Motion, deſcribes a Circle. If the *projectile* Velocity be ſo exactly adjuſted to the *gravitating Force*, as to balance each other in ſuch a manner that the Planet ſhall neither approach nearer to, nor recede farther from the Sun; in this Caſe, the Planet will deſcribe an exact Circle about the Sun. And it appears by Obſervation, that in the Revolutions of the Planets about the Sun, and the Satellites about the Planets, that the Squares of their periodical Times are as the Cubes of their Diſtances; therefore the gravitating Force by which they are retained in their Orbs, is every where reciprocally as the Square of their Diſtances.

And

explaining the Revolutions of Comets and Planets, without the help of etherial Matter.

Ariſt. But, *Eudoxus*, if Gravity continually gives Planets a tendency which directs them toward the Center of their Revolution, what hinders them from uniting with it, while betwixt them and this Center there is nothing at moſt but a Vacuity where Sight is loſt, an immenſe nothing? The Inhabitants placed by fine, fertile, and bold Imaginations, in the Moon, *Jupiter* †, and *Mars*, would probably have long ſince come to honour us with a viſit. Or rather they would have been, as well

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And the ſame holds true, if they are moved in any Conick Section; becauſe there is ſuch an affinity between a Circle and theſe Sections; and a Circle may be made to paſs into an Ellipſis, and an Ellipſis into a Parabola, and a Parabola into an Hyperbola.

And becauſe the Motion of a Planet is retarded as it recedes from the Sun, and accelerated as it approaches towards the Sun, the Planet always *deſcribes equal Areas in equal Times*.

This is the Nature of the Motion of all the Planets, as well the primary Planets about the Sun, as the Moons or Satellites about their own Planets; except that they are moved in Ellipſes not much different from Circles.

But the projectile Motion may be ſo very quick, that the Ellipſis, in which the Planet is carried, may become of a very great Length, and very excentrick: and a Planet moving in ſuch an Orb is called a *Comet*.

Nay, the projectile Motion may poſſibly be ſo much quicker ſtill, that the Planet may be carried in a Parabola, ſo as never to return again; but we do not know of any ſuch Motion in Nature.

Upon theſe Principles, the illuſtrious Sir *Iſaac Newton*, in his wonderful Book of the *Mathematical Principles of Philoſophy*, has explained the true Syſtem of the World, and ſhewn the true and adequate Cauſes of all the Celeſtial Motions, almoſt beyond the Genius of a Man. *Clarke's Rohault*, Vol. II. p. 74, *&c.*

† Riccioli Almag. T. 1. l. 4. c. 2. p. 187. Huygen, Entretiens ſur la pluralité des Mondes, par M. de Fontenelle.

well as we, a prey to the devouring Flames of the Sun.

Eudox. May we not ſuppoſe that the Stars at firſt receiv'd two Directions, the one perpendicular, which carries them toward the Center of their Revolution; and the other Horizontal, which removes them from it; and that in order to comply with the two Directions, they choſe to deſcribe a Circle?

Ariſt. On this Supppoſition, the Planets at firſt ought to have deſcribed a Diagonal, a right Line; as a Billiard-Ball, which upon a free Plane receives two Impreſſions in order to deſcribe a Square, deſcribes a Diagonal, a right Line; that it may comply with both Impreſſions: and a right Line would naturally enough carry a Planet into ſome fix'd Star, which would conſume and reduce it to Powder.

But pray, *Eudoxus*, whence would the Gravity * of Planets ariſe in a Vacuum? Should

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* Gravity or the Weight of Bodies is not any accidental Effect of Motion, or of any very ſubtile Matter, but an original and general Law of all Matter impreſſed upon it by God, and maintained in it perpetually by ſome efficient Power, which penetrates the ſolid Subſtance of it; for Gravity never is in proportion to the Superficies of Bodies, or of any Corpuſcles, but always to the ſolid quantity of them. Wherefore we ought no more to enquire how Bodies gravitate, than how Bodies began firſt to be moved.

Hence it follows, that there is really a *Vacuum* in Nature, and that it is much the greateſt part. For ſince Gravity is an univerſal Affection of Matter, if we ſuppoſe the World to be full, it would follow, that all Bodies would be equally heavy: Which is very abſurd.

This

Should it be from the nature itſelf of Bodies? But Bodies, which in their natural eſtate are only a Portion of modified Matter, have of themſelves no efficacy, no force, no biaſs to one Direction more than another; they are moſt indifferent. Thus whenever you give them a Direction, you ſee them follow it exactly, until ſome Obſtacle force them to quit it; and they follow it with ſo much the more conſtancy, the leſs the Obſtinacy is with which the Obſtacle reſiſts. Should it be from the motion, ſtroke, or impulſion of ſome foreign Body? But in the Vacuum, there is no ſuperiour Body, which could drive inferiour Bodies towards their Center. Should it be preciſely from the Will of God? But it is not the Will of God that the Bodies, which ſurround us, deſcend towards their Center, unleſs the Stroke and Impulſion of a foreign Body be ſome way concerned in it. A poliſhed Marble continues

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This being laid down for the Nature of Gravity; it will follow, that the Planets, if they have once impreſs'd upon them by God, the moſt ſimple projectile Motion in ſtraight Lines, will revolve about the Sun, as we ſee they really do in Circles or Ellipſes, without the help of Vortexes.

Hence it likewiſe follows, that if any very great Collection of fluid Matter be gathered together upon the Superficies of the Earth, it muſt flow backward and forward according to the various Motions of the Sun and Moon, becauſe of its gravitating towards them, in proportion to their Magnitudes and Diſtances. *Clarke's Rohault*, Vol. II. p. 97. See likewiſe the Notes to Converſat. 8. Vol. I.

nues faſtened to another, and under another; and yet it falls, when the Air, which flows between the two, thruſts it downwards. We do not ſee Bodies fall down, but only in Circumſtances in which we have ground to believe that they are precipitated by the Impreſſion of ſome ſuperiour Matter.

No doubt Planets ponderate; for in a word, ſince notwithſtanding their effort to remove from the Center of their rapid Revolution, they are always in the ſame Orbits, a real force muſt ſtay their effort, and repel them toward the Center of their Sphere. But it ſeems no leſs true, that they are carried in a vaſt Fluid; and this Fluid is probably the immediate Cauſe of their Gravity.

Yes, the Planets float in liquid Matter, diffuſed every where through the Heavens. At leaſt, one ſenſible Reaſon convinces me of it; here it is. If the Planets, Comets, and Stars, in whatever part of the Heavens they happen to be, are always viſible to the whole Hemiſphere of the Earth, and the Rays which make them to be ſeen are really material, ſo many Lines or Threads of Matter extended from the Stars to our Eyes; certainly the ſpaces in which the Planets have their Orbits, the ſpaces from which ſo long ago Comets have ſent forth Terrour and Dread upon the Earth; yea farther, the Regions in which we ſee Stars ſparkling, far from being Nothings of an enormous ſize, are filled with an immenſe Liquid.

But, 1. In whatever part the Planets, Comets and Stars are, we may ſee them from a whole Hemiſphere; in order to be perſuaded of this, we need only turn our Eyes toward the Heavens. 2. Luminous Rays are ſo many Lines, Threads of Matter. In ſhort, they cauſe ſome change in the Organs of the Eyes; they agitate them, and ſometimes wound them: therefore they touch them. Now it is only Body which externally touches Bodies; and every Body is material. 3. The Matter of the Rays ought to be extended from the Luminaries to us. For it tranſmits to our Senſes the Impreſſion which proceeds from the Luminaries; the Impreſſion cannot come from ſuch a diſtance but by Communication, which is ſucceſſively made to the Corpuſcles that compoſe the Rays; the Communication is made by a Stroke; a Stroke requires the Preſence of Corpuſcles, which ſtrike one another. Therefore the Heavens are not void of Matter; and etherial Matter ought to re-aſſume, or rather remain in poſſeſſion of the celeſtial Regions, which it has poſſeſſed from the Creation of the World.

Eudox. But ought not this celeſtial Matter to make every thing languiſh in the Heavens, and ſoon ſtop even the Courſe of the Luminaries, which would meet with Reſiſtance in it?

Ariſt. The Water of a rapid River * neither ſtops a Shallop, nor makes it flag, when it follows the Current of the Water. Why ſhould the Matter of the Heavens, this Matter ſo fine, ſo ſmooth in its Surface, ſo eaſy to be divided, ſo quickly ſtop the Luminaries, which followed its courſe in their Revolutions.

Eudox. You are determined, *Ariſtus*, not to part with your Vortices? The Idea of Vortices pleaſes you?

Ariſt. I think there muſt be ſome Vortices at leaſt round the Sun, *Jupiter* and *Saturn*, as we have obſerved in one of our Converſations [a], or we muſt renounce the Hypotheſis which makes the Light to come from the Stars to our Eyes, by the Motion of etherial Matter, in order to diſcover to us the Revolutions of *Mercury* and *Venus* round the Sun; and thoſe of the Satellites round *Jupiter* and *Saturn*.

Eudox. Accordingly Sir *Iſaac Newton* rejected this Hypotheſis [b].

Ariſt. Well! How then ſhall the Impreſſions of Light come to us from the Luminaries?

Eudox. Corpuſcles that iſſue from the Luminaries themſelves [c], and come all at once to us through enormous ſpaces, will convey thoſe Impreſſions in a few moments.

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* From what has been ſaid in Converſat. XV. p. it is evident that the Planets are not carried along in Vortexes of Matter as in a River.

[a] 15 Converſ. Vol. 3.

[b] See Notes, p. 50. Vol. 1.

[c] See Converſ. 22. Vol. 2.

Ariſt. But, 1. In what place do not the Sun or Stars make themſelves to be ſeen at the ſame time? And how can every one of thoſe Luminaries afford a ſufficient quantity of luminous Particles, in order to convey the Light themſelves into almoſt all the Corners of the Univerſe? In vain would the Sun be exhaled into Corpuſcles; he would not be ſufficient for it, he who is but a Point in compariſon of the Univerſe illuminated by his Light. 2. This would probably be but a ſmall Matter for ſuch luminous Corpuſcles, to make four or five hundred millions of Leagues in the ſpace of ſome few Minutes. 3. If the Particles of Bodies come ſo freely, and ſo rapidly to us, why may not celeſtial Bodies themſelves approach a little nearer to us, in an Hypotheſis in which no external Obſtacle ſtops them?

Eudox. A ſecret Virtue, *Ariſtus*, I know not what attractive Force, attracts the Light into the Eyes with an inconceiveable quickneſs.

Ariſt. This ſecret Virtue, *Eudoxus*, this attractive Force has ſomething in it, which ſeems a little myſterious, and too ſublime for us. Pray, do you explain it.

Eudox. According to the * Principles of Sir *Iſaac Newton*, a general Attraction reigns in the Univerſe. This Attraction is Gravity; and the Cauſe of it is unknown. Gravity or Attraction gives certain Bodies a Tendency, which carries them toward one another [d], whilſt a contrary Virtue, but equally incomprehenſible, ſeparates certain Bodies from one another [e]. Hence the regular Motions of Planets; a Gravity, a conſtant Attraction retains them in their Orbits in the Vacuity itſelf. Why is the Light ſpread over Bodies? I know not what Virtue attracts it over them. A Ball plunged into Water, aſcends again whenever it is at liberty; becauſe the Earth attracts the Water more ſtrongly [f]. Whence

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* Theſe Principles I conſider, ſays Sir *Iſaac*, not as occult Qualities, ſuppoſed to reſult from the ſpecifick Forms of Things, but as general Laws of Nature by which the Things themſelves are formed; their Truth appearing to us by Phænomena, though their Cauſes be not yet diſcovered. For theſe are manifeſt Qualities,

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lities, and their Cauſes only are occult. And the *Ariſtotelians* gave the Name of occult Qualities not to manifeſt Qualities, but to ſuch Qualities only as they ſuppoſed to lie hid in Bodies, and to be the unknown Cauſes of manifeſt Effects: ſuch as would be the Cauſes of Gravity, and of magnetick and electrick Attractions, and of Fermentations, if we ſhould ſuppoſe that theſe Forces or Actions aroſe from Qualities unknown to us, and uncapable of being diſcovered and made manifeſt. Such occult Qualities put a ſtop to the improvement of natural Philoſophy, and therefore of late years have been rejected. To tell us that every Species of Things is endowed with an occult ſpecifick Quality, by which it acts and produces manifeſt Effects, is to tell us nothing; but to derive two or three general Principles of Motion from Phænomena, and afterwards to tell us how the Properties and Actions of all corporeal Things follow from thoſe manifeſt Principles, would be a very great Step in Philoſophy, though the Cauſes of thoſe Principles were not yet diſcovered: And therefore I ſcruple not to propoſe the Principles of Motion abovementioned, *viz.* Gravity, and that active Principle, which cauſes Fermentation and the Coheſion of Bodies; they being of very general Extent, and leave their Cauſes to be found out. *Opticks*, p. 337.

From hence it appears, that our Jeſuit has either wilfully or ignorantly perverted the Meaning of this Great Man.

[d] See Notes, p. 119, & p. 177. Vol. I.

[e] Ibid.

[f] Ibid.

is it that Salt of Tartar is diſſolved *per deliquium?* The Vapours, which flutter in the Air, being attracted by this Salt, ſhake, break, and diſſolve its Particles. If Aqua-fortis diſſolves Silver, without changing Gold; if Aqua-regia diſſolves Gold, without changing Silver; this is not becauſe the Particles both of the one and other Menſtruum, are not fine enough to penetrate equally into the Interſtices of the Silver and Gold: but a ſecret Virtue attracts all the Violence of the Aqua-fortis into the Interſtices, and upon the Particles of the Silver, whilſt an oppoſite Force repels the Action of Aqua-regia; a ſecret Virtue attracts the whole Violence of Aqua-regia into the Pores, and upon the Particles of Gold, whilſt an oppoſite Force repels the Action of the Aqua-fortis [g]. Attraction produces all chymical Miracles, all Fermentations, all ſubterranean Fires, all the Fires in the Heavens, all Lightnings, all Thunders, and all the burning Heat of the Sun. The roundneſs of a drop of Water, of a drop of *Mercury*, of the Earth itſelf, proceeds from the ſame Principle. From this unknown Principle reſults the Beauty of the Univerſe [h]. Many Perſons of Judgment have gone into this Principle; and it daily gains new Partiſans in Countrys where Philoſophy is in eſteem.

Ariſt. Certainly, *Eudoxus*, that Naturaliſt, who brought this Principle into repute, muſt

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[g] See Notes Converſat. 3. Vol. 2.

[h] See Notes Vol. 1. p. 119.

have been as great a Philoſopher as he was, to call back with ſo much ſucceſs thoſe occult Qualities, thoſe active Virtues, which ariſe from the particular Nature of each Species, thoſe ſpecifical Virtues of Bodies; thoſe I know not whats, which for the ſpace of many Ages have produc'd the fineſt Phænomena of Nature.

Eudox. But he roundly declares, that he does not acknowledge thoſe Qualities[i].

Ariſt. But Attractions, whoſe Cauſe we are perfectly ignorant of, which excite no Idea in the Mind; and which nevertheleſs make up the Harmony of the Univerſe, are they not equivalent to occult Qualities? Theſe Attractions have not their Principle in Impulſion, ſince they make them reign even in a Vacuum. They do not refer them to the immediate Will of God*, which produces no change in Bodies that ſurround us; but in the moment that it is determined by Percuſſion. We muſt then conjecture Poſſibilities out of ſight, and throw ourſelves into Darkneſs on ſet purpoſe, or aſcribe Attractions to the Nature itſelf of Bodies; and if this is not to call back, in ſpight of one's ſelf, the Qualities proſcrib'd in ſeveral Places, it is at leaſt ſomething very like it.

Eudox. To aſſign ſuch Qualities for Cauſes to the Effects of Nature, would be to ſay nothing.

Ariſt. To aſſign attractive Virtues, of which one knows neither the Nature nor the Cauſe, for the immediate Principles of thoſe Effects, is this to ſay much more?

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[i] See Notes Vol. 1. p. 120.

* See Notes p. 304. *ſupra*.

Eudox. To acknowledge Gravity, and the Cauſe of Fermentation, that is, attractive Virtues, for the fertile Principles of Motion, although one be ignorant of the Cauſe of thoſe Principles, would not this be to have made great Progreſs in Phyſicks? Thus Sir *Iſaac Newton* propoſes thoſe Principles, as Principles of Motion.

Ariſt. Was it ever doubted, that Gravity and the Cauſe of Fermentations, were fertile Principles of Motion? If I am not miſtaken, to acknowledge that thoſe Principles of Motion conſiſt in Motion itſelf, and in Impulſion, would be to have made greater Progreſs; and I believe that this is a Progreſs, which has been made. For in a word, as we have remarked more than once, a Body is but a ſmall Portion of Matter; naturally it is only a Subſtance impenetrable, more or leſs long, large, deep, modified, and figured. In this there is no Biaſs, no Efficacy; a perfect Indifferency to Motion or Reſt, to ſuch or ſuch a Direction. Therefore a Body muſt receive Motion and Direction from ſome foreign Cauſe. Is this Cauſe the Will of Man? We may will as we pleaſe; inanimate Bodies neither move, nor change their Direction, without the Stroke or Rencounter of another Body. Is it preciſely the Will of God? No. The Author of Nature does not move the Bodies which ſurround us, nor change their Direction, unleſs the Stroke or Rencounter of another Body determine him. You do not ſee a Stone move without Impulſion toward the Eaſt or toward the Weſt, toward the North or toward the South; and we never ſee a Body change its Condition, nor Direction, but when we have ground to believe that Percuſſion has a ſhare in the Change. Iron moves as of itſelf to adhere to the Loadſtone: but we know that ſome imperceptible Matter comes out of the Pole of the Loadſtone, which enters again through the other Pole in form of a Vortex; ſince we ſee the Vortex deſcrib'd at once upon Filings of Steel; this Vortex attaches the Iron to the Loadſtone, or drives from between the Iron and the Loadſtone, the fine Matter or Air whoſe Elaſticity or precipitated Return thruſts the Iron toward the Loadſtone. Therefore Gravity, which carries Bodies towards a common Center, and Fermentation which agitates them univerſally, have their immediate Principle in Motion and Impulſion.

If Gravity carries ſenſible Bodies towards a Center, an imperceptible Matter ſtrikes and directs them. Why does Milk, which boils, ſwell by a ſort of Fermentation? The Corpuſcles of Fire, lighter than the ſurrounding Air, and thruſt upward, penetrate the Pores of the Veſſel, are rapidly darted into the Interſtices of the Liquid, and enlarge them ſo much the more, becauſe they dilate the internal Air; the Interſtices being enlarged, the Milk preſents to our Eyes a larger Bulk: this is a ſort of Fermentation, whereof Impulſion is the neareſt Cauſe, and which does not ſeem to proceed from an attractive Force, whoſe Principle is ſo deep a Myſtery. The Cauſe of other Fermentations is a Cauſe much like the ſame, according to what we ſaid when we had a Converſation upon Fermentations[k]. The Action of a ſubtile Matter always violently agitated, and the Springs of the internal Air, ſet at liberty in the mixture of Liquors, diſorder and diſſipate their Particles, and are the phyſical Principles of Fermentations.

Eudox. After all, *Ariſtus*, ſuppoſe we ſhould make the magnetick Virtue a little more general; ſuppoſe we ſhould extend a little farther, than what is ordinarily done, this Virtue of attracting, which is obſerved in *Spaniſh* Wax, in Amber, and in the Loadſtone, would this be claſhing with Philoſophy?

Ariſt. No: Two adjacent drops of Water, or two drops of Vinegar, *&c.* are eaſily united, ſo as to make only one drop, that we may conjecture ſome Species of magnetic Virtue to be in them. But I perceive in that, as in the Union of Iron and the Loadſtone, ſome impulſion. If, for example, ſome fine Matter iſſues out of a drop of Water, which finds an eaſier acceſs into another drop of Water than into the Air, the fine Matter paſſing with united forces from one drop into another, will drive out the Air from between the two, and take away the Equilibrium; and the external Air, which will puſh them, will at once re-unite both in one. But they will have Tendencies and Attractions without Impulſe, without Percuſſion; ſince they will have the Planets to attract one another, without letting go their hold, in Vacuities almoſt infinite; and this is what is no more probable upon your Principles, *Eudoxus*, than mine.

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[k] 2 Converſ. Vol, 2.

Eudox. Formerly, *Ariſtus*, you jeſted upon ſubtile Matter [1], and to-day you take upon you the Defence of it in good earneſt, and diffuſe it every where.

Ariſt. This Matter, however minute it may be, ſeems to me to be too ſerviceable to thoſe very Perſons who diſown it, for me not to intereſt myſelf in its behalf. If they do not receive it from the hand of M. *Deſcartes*, I wiſh they would condeſcend to receive it from the hand of *Ariſtotle*. This ancient Philoſopher made uſe of it to fill up all the Interſtices of Bodies, ſince he allowed no Vacuum in the Univerſe. Thus beſide the Fire, Air, Water and Earth, he acknowledged a fifth Species of Matter diffuſed every where, which he called the Æther. Is not this the ſubtile Matter?

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[1] 5 Converſ. Vol. 1.

Eudox. But this fine Matter, which overflows the Univerſe, whence has it its Motion[*], its Force?

Ariſt. From God; for to conclude, there muſt be a firſt Cauſe of Motion?

Eudox. On the firſt opportunity, *Ariſtus*, let us make God himſelf the Subject of a Converſation. Let us endeavour to aſcend by created Beings, as by ſteps, to the Creator. This is the end of Philoſophy. God was the beginning of our Converſations, let him alſo be the end of them.

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[*] *If Gravity depended upon any known Law of Motion, it ought to be referred to a ſtroke from an extraneous Body*; *and* becauſe Gravity is continual, *a continual Stroke would be required.*

If there be ſuch a ſort of Matter continually ſtriking againſt Bodies, it muſt of neceſſity be fluid and very ſubtile, ſo as to penetrate all Bodies; for Bodies that are any how ſhut up in others, are heavy.

Now let a Mathematician conſider, whether a Fluid ſo ſubtile, as freely to penetrate the Pores of all Bodies, and ſo rare, as not ſenſibly to hinder the Motion of Bodies, (for in a Place void of Air, the Motion of a Pendulum will be continued very long) can impel vaſt Bodies towards one another with ſo much force? Let him explain how this Force encreaſes in a Ratio of the Maſs of the Body towards which another is carried.

Laſtly, Let him ſhew, what ſeems moſt difficult to me, how all Bodies, in any Situation whatſoever (if the Diſtance, and the Body towards which the Gravitation is, remain the ſame) are carried with the ſame Velocity; that is, how a Liquid which can only act on the Surfaces, either of the Bodies themſelves, or their internal Particles, to which it is not hindred from coming by the Interpoſition of other Particles, can communicate ſuch a Quantity of Motion to Bodies, which in all Bodies exactly follows the Proportion of the Quantity of Matter in them; which is proved to obtain every where in Gravity.

Yet we do not ſay, that *Gravity does not depend upon any Stroke*, but that it does not follow from that Stroke, *according to any Laws known to us. s'Graveſande's Phyſ. Elem.* Vol. II. p. 215.

CONVERSATION XXII.

Upon the Exiſtence of GOD.

Ariſt. OFTEN, *Eudoxus*, have you made me obſerve in Nature, Characters of a Wiſdom wholly divine. I always conſidered them with new pleaſure; and ſhould be overjoyed if you would bring them to my remembrance, and make me to ſee with the Eye, if poſſible, by what ſteps you aſcend as a Philoſopher, even to God himſelf.

Eudox. 1. I have a Body, this I can't doubt of. My Body has received Being from a great number of Bodies, ſucceſſively born of one another. I ſee the ſame Succeſſion both in Plants and Animals, in all Species of organized Bodies.

2. If all theſe ſucceſſive and organized Bodies are of themſelves only poſſible, if their Nature or Eſſence is not Being itſelf; there muſt be, without the Aſſemblage of thoſe Bodies, a neceſſary Being, from whom every Species has received its Exiſtence. If every

thing were poſſible only of itſelf, no Species of Body would exiſt; for no Species of Body would have a Principle or Source of Being neither in itſelf, ſince of itſelf it would only be poſſible, and what has not Being, cannot give it; nor in any other actual Being, ſince every other thing being of itſelf only poſſible, would have no efficacy; nor in Non-entity, ſince Non-entity, which is nothing, and which contains nothing, produces nothing. But all ſucceſſive and organized Bodies are of themſelves only poſſible; none of them had Being in its Eſſence. We ſee them all ſucceed one another, change, and diſappear. Therefore without the Collection of thoſe Bodies there is a neceſſary Being, from whom every Species has derived actual Being.

3. This neceſſary Being is an intelligent Being. The Art, which manifeſts itſelf in the Structure of Bodies, which owe their Being to him, is the Seal of Intelligence. Who put this Heart into my Breaſt[a], which dilates itſelf to receive the Blood, and is alternately contracted, in order to throw it with violence into an Artery, which is divided into thouſands of imperceptible Branches, in order to convey Blood, Nouriſhment, and Life into all the parts of my Body? Who placed the Veins above the Arteries, in order to carry back and perfect the Remainders of Blood in the Focus of the Heart? Who diſpoſed thoſe Valves in

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[a] 9 Converſ. Vol. 2.

the Arteries, thoſe Species of Suckers, which permit the Blood to flow from the Heart or Center to the Extremities, oppoſing its return [b]? Who had skill, on the other hand, to inſert into the Veins thoſe Valves, thoſe Suckers, which permit the Remainders of Blood to return toward the Heart, to be purified there, without allowing it to flow back toward the Extremities? Whence come thoſe Paſſages, thoſe Valves ſituated a contrary way, thoſe Vents ſo well diſpoſed in the right Ventricle of the Heart, which direct the Blood through the Branches of the pulmonary Artery, into the Lungs to be cooled, thereby receiving the Air, which Reſpiration brings thither thro' the Trachea? The Mechaniſm of the left Ventricle of the Heart is no *leſs* ingenious, nor leſs happy for receiving the cooled Blood, and continuing the Circulation, which diſtributes the Aliments. But the Blood is conſumed by Nutrition and Tranſpiration. The Buſineſs is to repair it by new Nouriſhment *. I need only will it. The Spirits flow in the Nerves; the Muſcles are inflated, fall again, are lengthened and ſhrink; the Teeth being ſolid and ſharp, break the new Nouriſhment: The Epiglottis, like a Sucker, or a Draw-bridge, lowers itſelf to let the comminuted Nouriſhment deſcend into the Stomach, without hurting the Trachea. The

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[b] 8 Converſ. Vol. 2.

* 9 Converſ. Vol. 2.

Stomach incides them with its Acids, and digeſts them. The beſt digeſted Juice is fine enough to be filtred through a thouſand Interſtices. The Preſſure makes it paſs from the Interſtices into the lacteal Veins, thence into the Channel, which carries it, by the help of certain Valves, into the Veins, which convey it into the Heart to be purified there by Fermentation. By virtue of fermenting and circulating with the Blood, it takes the Nature of Blood itſelf, in order to cheriſh Life univerſally, to temper and mix thoſe Colours, which ſpread over the Countenance a lively Complexion, and make a Carnation which Art can never imitate but imperfectly. How well is this Mechaniſm contrived!

But how do I ſee at once the Sea, the Earth, and the azure Heavens beſpangled with a million of luminous Stars? How do ſo many immenſe Objects come to be ranged in ſo ſmall an Organ*? The Eye, in which a celeſtial Flame ſhines, is round. Its Surface receives Rays from a greater number of diſtant Places. Thoſe Rays, broken by the different Texture and Figure of the Humours of the Eye, continue to approach one another, till the Rays parted from every Point of the Objects, are united upon the Retina, and convey thither the Impreſſions which they have received †. Hence, the Impreſſions, the faithful Images of Objects, from the Sun even to Atoms, paſs through the Fibres of the optic Nerve into my Brain, in which whatever is moſt wonderful in the Univerſe, ſeems united on a ſudden.

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* 20 Converſ. Vol. 2.
† 15 Converſ. Vol. 3.

But how is it that I find, even when my Eyes are ſhut, all the Images I pleaſe in my Brain to the degree mentioned above? I call them, and immediately they preſent themſelves. I diſperſe them, and they diſappear*. I need only will it, and forthwith they return. Is this a Cabinet of Paintings, whoſe Pictures are ready of themſelves to be ranged at my pleaſure? The Changes which are made in the Subſtance of my Brain, are new Images, more reſembling, a thouſand and a thouſand times better finiſh'd than the Maſter-pieces of *Rubens*, *Titian*, or *Zeuxes*. Whence ariſe thoſe Textures of Particles in this ſoft Subſtance, in this Species of Clay, ſo docile both to the Impreſſions of the Objects which ſtrike my Senſes, and alſo to the Deſires of my Will?

This marvellous Art, this Deſign ſo well concerted, which I obſerve in my Heart, Arteries, Veins, the Motion of my Blood, the Organs of my Senſes, my Eyes, and Brain; I alſo remark it in all the parts of my Body. It is manifeſt, as we have already ſeen, in the Animals which are millions of times ſmaller than a Mite, than the loweſt perceptible Inſect. This Art, this Deſign, is above the reach of all Men, even the moſt knowing, though all their Wits were united together, to invent, comprehend, or to imitate.

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* Demonſtration de l'Exiſtence de Dieu, proportionnée à la foible intelligence des plus Simples.

Could the firſt Being, the neceſſary Being, who formed the different Species of Animals, make ſo much Art to ſhine univerſally without Underſtanding? Could an irrational and blind Being have a thouſand and a thouſand times more Judgment, Wiſdom, and Skill than all Mankind together?

But what could not Chance make, that obſcure Abyſs, in which ſome will have the Mind to be loſt? Or ſhall we rather ſay, what could it make regular? Chance is only a little Matter agitated, which always tends to move in a right Line, irrational and blind. Is it ſurprizing, that for the ſpace of ſix thouſand Years it has made, at moſt, but ſome deformed Caverns, not one mean Inſect, that we know of, nor one Blade of Graſs? If I ſuſpected a Watch to be the Workmanſhip of Chance, I ſhould paſs for a Fool equally, and with reaſon, in the Judgment of a wiſe Man, and in the Judgment of an incredulous Perſon. What would it be, if the Watch ſhould wind up itſelf, as my Body renews itſelf; if the Watch were as docile and as ſubmiſſive to my Will, as my Body; if the Watch folded up itſelf, defended itſelf, and run away like the Body of an Animal, to preſerve itſelf; if the Watch produced itſelf a-new in other Watches? To honour Chance with the Mechaniſm of an organized Body, is deſignedly to prefer Darkneſs to Light, acknowledged at the bottom by a Sceptick, as well as a Philoſopher.

If a Man, if a Philoſopher ſhould take it into his head to ſay, upon ſeeing *Verſailles*: "How fooliſh are Men! They imagine that "it requires ſome well-skill'd Architect to "build the fineſt Palace. But this Palace ſo "much boaſted of, how was it reared? The "Stones agitated by I know not what for"tuitous Motions, without the Action of any "Intelligence, did iſſue out of the boſom of "the Earth. They were hewn out of them"ſelves, by encountering one another; they "were thrown and ranged above one an"other. The Marble imitated them. The "Stones and Marble had skill of themſelves "to form thoſe Rooms, thoſe Galleries, thoſe "Halls, this Edifice which ſurprizes all Na"tions. The Wainſcoat, the Gilding, the "Cieling, the Paintings ſo finiſh'd, which "have ſo much Grace, Majeſty, and Life, "thoſe Glaſſes in which one ſees one's ſelf "produc'd again on all ſides, thoſe delicious "Gardens, thoſe Fountains which riſe to the "Clouds, thoſe Pictures which ſeem to think, "and thoſe Statues which ſeem to talk; "all this is only the Game of Chance." No Man would be ſo ſimple, no ſound Mind would be ſo fantaſtick as not to judge the pretended Philoſopher worthy of a Mad-houſe. In vain he might ſay: “ But after all, I do “ not clearly ſee the Impoſſibility of what I “ advance.” That is not at all aſtoniſhing, might we anſwer him, (if however we would vouchſafe to make him any Anſwer) ſince you do not ſee that it is even Madneſs itſelf which dictates what you advance.

Now there is infinitely more Art in an animated Body, in the vileſt Inſect, than in the moſt curious Watch, or the moſt admirable Palace. Men are capable of inventing this Watch, and of raiſing this Edifice; but they can invent nothing, execute nothing which approaches an animated Body, even the vileſt Inſect.

To conclude, could Chance, or I know not what Collection of agitated Matter, give us Veins for containing the Blood, a Heart for receiving, perfecting, and diffuſing it; Nerves and Muſcles for the Motions of the Body, Spirits for the Mechaniſm of the Nerves and Muſcles *, Lungs for Reſpiration, Feet for walking, a Palate for taſting, a Noſe for ſmelling, Eyes for ſeeing, Ears for hearing, a Voice for communicating our Sentiments, and for enjoying what is moſt agreeable in Life, the Converſation of Men, and of our Friends? Deſigns thus executed, are not the Productions of blind Matter, of

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* Vol. 2. Converſat. 8 & 9.

a forſuitous Motion. Therefore it is evident that the neceſſary Being, who gives Exiſtence to the different Species of Animals, is an intelligent Being.

4. This neceſſary and intelligent Being is not at all Matter; Matter and this intelligent Being are two Subſtances, two Beings really diſtinct. This intelligent Being thinks; forms the beſt contrived Deſigns, and executes them. Matter does not think at all. If Matter did think, which in its natural State is only Extenſion, Extenſion would think; whereas Extenſion has no Thought. Otherwiſe, Thinking would be a manner of Being, a Modification of Extenſion, and conſequently a Thought would be a modified Extenſion. Now Thought is not Extenſion. Extenſion is diviſible, coloured and figured. But in vain ſhould I attempt to divide a Thought. Judgment, whether affirmative or negative, has no parts which one can divide; Love has none. I may do what I pleaſe, I cannot form a fourth, a half, nor three fourths of a Judgment or Act of Love. It is a Teſtimony of my Conſcience itſelf, which aſſures me of it, an internal Sentiment which cannot deceive me. Pray, what Colour does one perceive in Love, or in Hatred? What Figures have our Judgments, our Paſſions? Are they Triangles or Squares? Therefore Matter does not think at all.

Every part of Matter join'd to another, makes a Figure; but I may vary my Thoughts as I pleaſe, and match them differently, I always perceive the Changes of my Sentiments, but never their Figure.

Matter is naturally ſuſceptible only of Reſt, Motion and Figure. And neither Figure, nor Motion, nor Reſt, are Thought. My Body paſſes from Reſt to Motion, from Motion to Reſt, and aſſumes a new Figure, without any viciſſitude of Thoughts. If the Changes of my Body were ſo many new Thoughts, I ſhould be ſenſible of them. We are admoniſh'd by internal Senſation concerning whatever paſſes in our Thoughts.

Probably the Food, which we take, thinks not at all. Should it begin to think after it has paſt into the Subſtance of our Bodies, where all is diſſipated and renewed by an imperceptible Tranſpiration, and by a continual Succeſſion of Nouriſhment? Our Thoughts would be exhaled by Tranſpiration. The ſame Thoughts however are found again in us, whenever we have a mind; we need only will, and the Thoughts of Infancy itſelf return, and preſent themſelves to us.

Finally, the fineſt and moſt agitated Atom cannot be in an inſtant both in the boſom of the Earth, and alſo in the higheſt part of the Heavens; it is not every where at the ſame time. My Thought in a moment penetrates the Heavens and the Earth; my Thought is in a thouſand and thouſand Countrys at a time! In the twinkling of an Eye it embraces the moſt extended and moſt univerſal Object. I will it; and already it has run over the whole Univerſe.

Therefore the neceſſary and intelligent Being, and Matter, muſt be two Subſtances really diſtinct. In a word, the neceſſary Being, who gives being to different Species of Animals, is a Spirit. This is preciſely what the *Epicurean* and *Spinoſiſt* would not acknowledge, if they could.

5. What difference between this Spirit, and the Spirit which thinks in me! That knows perfectly the Mechaniſm of Bodies. It had skill to form, and plentifully to ſpread over the Surface of the Earth, innumerable Species of Plants and Animals, in which my Spirit inceſſantly diſcovers new wonders, which it ſcarcely knows how to admire, and which it can neither imitate nor comprehend *.

6. A Spirit, who knows how to make ſo wonderful an uſe of Motion, ought to be himſelf, I think, the firſt Mover, if the firſt Principle of Motion is external to Matter. For in a word, this Principle muſt be a Subſtance different from Matter, or Motion muſt be eſſential to Matter, or Matter muſt give itſelf Motion. Matter does not move eſſentially. In its natural Condition, it has nothing

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* Converſ. 6. Vol. 3.

thing but Extenſion. The Idea which repreſents it to us, founded upon Experience, offers no other thing to our Minds. And it is evident, that Extenſion may ſubſiſt without Motion. The Mind diſcovers in it nothing but a perfect Indifferency to Motion or Reſt. Thus we ſee the ſame Body ſometimes in Reſt, ſometimes in Motion. By the ſame reaſon, Matter does not move itſelf, ſince it is in a perfect Indifference, without force, without biaſs, and without efficacy. Hence a thouſand ſenſible Bodies remain whole Ages in the ſame Place, until ſome foreign force come to diſplace them. Therefore Motion, which ſeems to animate inanimate Bodies, Luminaries, the Heavens, the Univerſe, proceeds from a Principle external to Matter. Therefore the Spirit, neceſſary and ſuperiour to all human Intelligence, is the firſt Mover.

7. This Spirit, the firſt Mover, is not a Soul ſubſtantially united to Matter, and which alone, as the *Pythagoreans* imagined, animates the Univerſe, and all the Bodies which compoſe it. This Soul muſt neceſſarily have a thouſand Qualities ſtrangely oppoſite in different Bodies; without knowing it. It would be at the ſame time ignorant and wiſe, dark and enlightned, full of Contempt for what it eſteemed, of Love for what it hated, peaceable and furious, a Friend and Enemy of Laws, pious and impious, virtuous without virtue, free without liberty, happy and unhappy.

How could a knowing, wiſe, and ſimple Spirit, who cannot be ignorant of what paſſes within itſelf, contain ſo many Varieties, Caprices, and Contradictions, without its knowledge?

8. Notwithſtanding the Spirit, the firſt Mover, who regulates and directs the Motions of the Univerſe, poſſeſſes Immenſity; his Action makes itſelf felt throughout the whole Univerſe. This Spirit is independent, ſince he derives his Being from his Eſſence itſelf. He is eternal; what cannot but exiſt, can neither begin, nor ceaſe to be.

9. The independent, eternal Spirit has no need of external and ſenſible Beings, whoſe Structure and Motion conſtitute the Beauty of the Univerſe, ſince having produc'd them, he contains them eminently in himſelf. Therefore he has produc'd and does preſerve them freely; he is free. And ſince the Production and Preſervation of the viſible World depend upon his Will, Wiſdom, and Power, he muſt be the Maſter and Ruler of the Univerſe; the Sovereign of Heaven and Earth. Therefore there is a neceſſary Spirit, diſtinct from the Univerſe, the Author and Sovereign of the Univerſe. Theſe are, *Ariſtus*, ſome of the Steps by which my Mind aſcends even to God himſelf.

10. In order to reach thither ſtill more ſwiftly, nothing more is required than a ſingle Glance of the Eye. This exceſſive plenty

of Stars[*], thoſe pure Fires, do not ſparkle in the dark Azure, but to diſcover to us the hand of God in all his Works. Night proclaims it to Day, and Day to Night. I perceive Characters of his Simplicity even in the diverſity of Plants, Flowers, Fruits, Animals, Faces, Sounds and Colours[c]. I ſee Characters of an unchangeable Being in the regular viciſſitudes of the Seaſons; his Liberality in the Treaſures of the Earth; his Providence in thoſe extended Plains covered with rich Harveſts; his Greatneſs in thoſe Abyſſes of Air and Water, in this immenſe Vault of the Heavens. We every where ſee his Wiſdom ſhine, which forms the Light to illuminate us; the Air, for Reſpiration; the Heat, for cheriſhing the Principle of Life which we bear in ourſelves; the Plants, to furniſh us with wholeſome Food, and Remedies for Diſeaſes; the Bees, to act with an Order which may ſerve us for a pattern[d]; the Sea, to be the Center of Commerce; the Clouds, which fly as upon the wings of the Wind to water the Fields; the Sun, to enlighten, render fruitful, and animate all by his beneficent Aſpects; the Moon and Planets[e], to remit to us at leaſt ſome Rays, when the Sun goes to miniſter elſewhere; the Day, for being the time of

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[*] 14 Converſ. Vol. 3.
[c] Converſ. 1,2,3,4,5,6. Vol. 3. Converſ. 13,22,23,24. Vol. 2.
[d] 6 Converſ. Vol. 3.
[e] 12 & 13 Converſ. Vol. 3.

Labour; the Night, to encompaſs the Earth with its Shades, to ſpread Silence thereon, to refreſh the Body, and to recruit the Spirits; the Morning, to bring back the Day, to call Man again to labour, to revive the pleaſures of Society, and to re-animate Nature.

11. But why need I run through ſo many pieces of Workmanſhip that have come out of the hands of God, that I may ſtill diſcover new Perfections in him? Perfection itſelf, Being is his Eſſence, his Nature *. He is independent;

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* *God governs all things, not as a* Soul of the World, *but as the* Lord of the Univerſe.———God, *is a relative word, carrying in it the Notion of Relation to* Servants. *And the* Godhead *of God is His* Dominion: *A Dominion, not like that of a Soul over* its own Body, *but that of a* Lord over his Servants.———*God is* Eternal *and* Infinite, Omnipotent, *and* Omniſcient: *That is, he endures from Everlaſting to Everlaſting, and is preſent from Infinity to Infinity: He governs all things which are, and knows all things which are poſſible to be known. He is not* Eternity *or* Infinity, *but* Eternal *and* Infinite. *He is not* Duration *or* Space; *but He* endures, *and is* preſent. *He endures* always, *and is preſent* every where; *and, by exiſting always, and every where, conſtitutes* Duration *and* Space; *Eternity and Infinity. Seeing every Particle of Space is* always, *and every indiviſible moment of Duration is* every where; *ſurely it cannot be ſaid of the Maker and Lord of all things, that He is* [at no Time, *and* in no Place] never *and* no-where. *He is Omnipreſent, not only* virtually, *but* ſubſtantially: *For* Power *cannot ſubſiſt without a* Subſtance. *In Him all things ſubſiſt and move, but without a mutual affecting each other,* [ſuch as is between Soul and Body] *God is no way affected by the Motions of Bodies; and the Motion of Bodies meets with no Obſtruction from the Omnipreſence of God*———*He is altogether without* Body *or* Bodily Shape; *and therefore can neither be ſeen, nor heard, nor felt, nor ought to be worſhipped under the ſimilitude of any corporeal Thing. We have Ideas of His* Attributes; *but what the* Subſtance *of any Thing* is, *we know not at all.——The very* Subſtances themſelves, *even of* Bodies, *we cannot come at the Knowledge of, either by any of our Senſes, or by any* reflex Act of the Mind: *much leſs have we any Idea of the* Subſtance of God. *Him we know, only by His* Pro-

dependent; nothing external can limit him; there are no reaſons for attributing to him one Perfection rather than another. Could he be limited by himſelf? Could his Nature require Bounds? But Perfection, but Being needs no Bounds; this would be to tend to his own Deſtruction, to Non-entity, ſince Bounds are a Negation, Non-entity itſelf. Therefore a neceſſary, independent, eternal Spirit, God, in one word, poſſeſſes fulneſs of Being, of Perfection. Now all poſſible Perfections, Knowledge, Juſtice, Liberty, Power, *&c.* are ſo many degrees of Being: Therefore God contains all poſſible Perfections: Therefore he is infinite, and is an infinitely perfect Spirit.

12. It is evident, that Matter is not an infinitely perfect Being, no more than our Spirits, whoſe Bounds we are ſenſible of. It is diviſible; Diviſion takes away from it the Perfection which it had. It cannot give itſelf Motion; it muſt borrow it from ſome foreign Cauſe; it loſes it without poſſibility of producing it again. It does not think; it is blind, irrational, as we have obſerved. Therefore it is not a neceſſary Being; therefore of itſelf it is only poſſible; therefore it has received Being as well as Motion; therefore

Properties *and* Attributes, *and by His moſt* Wiſe *and* Excellent Diſpoſition *of* Things, *and by* final Cauſes: *and we adore and worſhip Him, upon account of His* Dominion. *For a* God *without* Dominion, *without* Providence, *and* final Cauſes, *is nothing but* Fate and Nature. *Newton's Princip. Schol. General.*

fore Reaſon in concert with Faith, teaches us that there is a Spirit really diſtinct from the Univerſe; a Spirit, the Creator of Heaven and Earth; a Spirit who formed out of Nothing both Heaven and Earth: and this is the God whom my Mind acknowledges, and my Heart adores.

Ariſt. Do you comprehend, *Eudoxus*, how the *Spinoſiſt* can take upon him to advance, that he diſcerns only one Subſtance; that this one Subſtance has two eſſential Properties, namely Extenſion and Thought; and that the different Beings, which compoſe the Univerſe, are only Modifications of thoſe two Attributes, which ſucceed one another by an eternal and neceſſary Concatenation?

Eudox. That is claſhing with Reaſon, 'tis true, ſince Spirit and Matter are Subſtances evidently diſtinct; it is raſhly to confound the Worker with the Work; it is to annihilate the Creator, to ſubſtitute the Creature in his ſtead. But when Paſſion, Extravagance, and Impiety have taken poſſeſſion of the Mind and Heart, what Monſter is not one capable of bringing forth? *Spinoſa*, born in the laſt Age, but born and educated in Judaiſm, carried the Blindneſs and Hardneſs of it much farther than his Fathers. He abjur'd their Faith; but this was only in attempting to deſtroy that God whom they worſhipped from the Birth of the World. And how dares he attack him? By Reaſonings that proceeded from his Heart rather than his Judgment. He begins with laying down this for a Principle, That whatever exiſts, and is conceived alone, without the Idea of another Being [f], is a Subſtance. So far his Judgment is ſound. But then he immediately concludes, that there never was but one Subſtance. It is his Heart alone which concludes after this manner: *The Fool ſaid in his Heart*, Dixit inſipiens in corde ſuo [g]. For in ſhort, thus, I think, a ſound Judgment would reaſon: Whatever exiſts, and is conceived alone, without the Idea of another Being, is a Subſtance. This Principle is indiſputable. But every one may know by the Teſtimony of his Senſes, and by an internal and infallible Sentiment, that there is a great number of things, which are conceived alone, without the Idea of another Being; ſuch are a Circle, a Roſe, a Diamond, a Man, *&c.* Therefore it evidently follows from *Spinoſa*'s Principle, that there are in the Univerſe ſeveral Subſtances; and the firſt Attempt which he makes to drain the Source of Truth, throws him into an unpardonable Contradiction. But how ſhould one attack the Principle itſelf of Reaſon by judicious Reaſonings?

Does *Spinoſa* reaſon better, when he pretends that his Subſtance has two eſſential Properties, Extenſion and Thought? No indeed.

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[f] Ethices, pars 1. p. 1. & 6.

[g] Pſ. 52.

Two eſſential Properties of one and the ſame Subſtance ariſe from the Nature of the Subſtance; they are not really diſtinct, they are the Subſtance it ſelf. The Properties of a Triangle do not differ from the Triangle; the one is really the other, they are the Triangle itſelf. This being granted; if Extenſion and Thought are the eſſential Properties of one and the ſame Subſtance, of an individual Subſtance, they are really the ſame thing. Therefore Extenſion muſt think. But as we have obſerved, Extenſion does not think: if Extenſion thought, a Thought would be a modified Extenſion; whereas Thought is no Extenſion. Extenſion is diviſible, figured and coloured; but in vain ſhould I attempt to divide a Thought, a Judgment, an Act of Love. Love has neither Colour nor Shape. An internal Perception, which is not liable to Deluſion, and does not ſuffer us to doubt of it. Therefore Thought is not Extenſion. Truly, if we could ſuſpect that Stone and Iron think, the Sympathy of the Loadſtone and Iron would in that caſe be a real Paſſion. But then we muſt ſay a piece of Thought, as they ſay a piece of Stone, or of Iron, and extinguiſh all the Light which we receive from our Senſes or Reaſon. Therefore the ſingle imaginary Subſtance of *Spinoſa* cannot have two Properties, whereof the one is Thought, and the other Extenſion. Therefore the great Principle of the moſt famous among the modern

Atheiſts has nothing in it but what is frail, and much better demonſtrates the Perverſeneſs of his Heart, than the Strength of his Judgment.

I queſtion, *Ariſtus*, whether you will find him more reaſonable, when he imagines the Univerſe to be the Reſult of the Modifications of two incompatible Attributes, to be a Concatenation of neceſſary Productions, in which only a natural and incomprehenſible Neceſſity bears ſway, and when he gives to this imaginary Concatenation, to this ſenſible Univerſe, the Name of an infinitely perfect Being.

Ariſt. 1. The Univerſe cannot be the neceſſary effect of the Modifications of two chimerical Attributes.

2. Man is free; an inward and real Perception convinces us of it. Why cannot we doubt of the Exiſtence of Thought? Becauſe we are conſcious of it. We are equally conſcious of Liberty. Liberty makes all Men conſcious of it: therefore all Men are free. Thus the perſuaſion of it is general. It is one of thoſe firſt Truths engraven deeply on the Soul, and which it is in vain for one to attempt to wear out. But how could Liberty ſubſiſt, where only a natural Neceſſity prevail'd?

3. The Univerſe is diviſible, ſubject to a thouſand Changes, to a thouſand Viciſſitudes; Ignorance, Vice, and Diſorder, reign therein amongſt Men in a thouſand Places; there the Brother pollutes himſelf with the Blood of

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his Brother; there the Son waits for the Death of his Father. How many Perſons unhappy throughout their whole Lives! What do I ſay? In *Spinoſa*'s Principles, the Univerſe is but one Subſtance, it is properly only Matter, without Spirit, without Liberty; in it, one is happy and unhappy without deſerving it, without knowing it. Do they think that they are ſpeaking to Men, when they abuſe Terms ſo far, as to proſtitute to an heap of ſo many Imperfections the Name of an infinitely perfect Being, which Reaſon hath always conſecrated to the ſupreme Being, to the Spirit, Creator of the Univerſe. They muſt have a ſtrange deſire to declare themſelves Atheiſts, and to exceed the Incendiary of the Temple of *Epheſus*, in order to make themſelves famous. After all, *Eudoxus*, I underſtand that the Heart endeavours to make Atheiſts, and that there are hypocritical Profeſſors of Atheiſm: But do you believe that there are real Atheiſts among the Incredulous, or among the Wits of our Days?

Eudox. A real Atheiſt would be a Man, who making uſe of his Reaſon, would judge, and perſuade himſelf that there is no God [*]. But how can any one judge and perſuade himſelf that there is none, and yet make uſe of his Reaſon? The Mechaniſm of the Human Body, the wonderful Union of Body and Soul, ſo-

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[*] As Father *Tournemine* obſerved in his Reflections upon Atheiſm.

ſo many Species of Plants and Animals, the Motions and Splendour of the Luminaries, the alternate Succeſſion of Day and Night, the Viciſſitudes of the Seaſons, the Order and Harmony of the Parts of the World, all declare to us, all reveal to us a Being ſuperior to all that we ſee, a Spirit Creator of the Univerſe, a God. There is no reaſon for not acknowledging him. *I do not evidently ſee; I do not comprehend:* Here it is that all the Reaſons of the Infidel terminate. As if the Weakneſs of our Minds ought to comprehend the whole depth of the moſt ſublime Being, and the firſt of Beings; and as if Incomprehenſibility ought not to be one of the Prerogatives of the ſupreme Being, of the Spirit who had the skill to create Man; Man, I ſay, who does not comprehend himſelf. Thus an hundred impious Perſons being converted, have acknowledged, that in vain they had attempted to put out that Light which enlightned them concerning the Beginning and End of Man. Thoſe who were not converted, have they been beyond all doubt[b]? Two or three have carried their Infatuation even into the middle of the Flames; but ſhall we not believe that Folly, Deſpair, Madneſs, precipitated them into it rather than a perſuaſion of their Judgment? If they were perſuaded upon ſolid Reaſons, they had no more to do but to diſſemble a moment. And by that means they would have prolonged their

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[b] Reflections upon Atheiſm.

Days; they would have eſcap'd the Violence of the Flames; they would have ſecured to themſelves the only Good which they could expect. Far from diſgracing themſelves, they would have prevented the ſhame of dying looked upon as Monſters of Nature, and accurſed by the whole World; and in ſuch a Perſuaſion, they would have ſeen nothing to be feared on the part of an avenging God.

Ariſt. What has ſurprized me more than once in certain Companies, and what ſurprizes me as much almoſt as thoſe blind Tranſports, is the Licentiouſneſs with which Perſons, otherwiſe civiliz'd and ingenious, run out ſometimes in ſpeaking of what is moſt real and venerable. They are favoured by Fortune; they have diſcovered ſome Secrets of Nature; they know how to turn a Thought, or a Verſe. This is enough; without waiting for Age, they have a right to judge ſovereignly of all Things; what is the moſt ſublime muſt be brought before their Tribunal. If any difficulty occur above their reach, if they do not comprehend the moſt elevated Myſteries, they will not impute the Fault of that to the Weakneſs of their Judgment; they owe no ſubmiſſion but to Evidence. When we do not believe them upon their Word, we are in the wrong; and whilſt they ſee the moſt Wiſe, moſt Skillful, and moſt Learned, give up themſelves to the Voice of Nature, and reverence its Author, they ſeem, in ſpight of Evidence itſelf, to ſearch out Reaſons for doubting, or of infuſing Doubts into the Minds of others, in order to quiet the Remorſes of their Conſcience by the apparent Multitude of Unbelievers. They will be credulous in the Commerce of civil Life. You would ſay, that Doubting ſeems not to be permitted them but when they attack the Foundations of Religion. Every thing preſents a God to them, whom they deſire never to ſee.

Eudox. That is as much as to ſay, that Talents and Benefits make Men ungrateful toward the moſt liberal of Benefactors. We enjoy the Light, and yet will not lift up our Eyes toward the Luminary which makes it ſhine upon us. Paſſion is afraid to ſee all that may mortify it. An Idea of a God of Vengeance humbles Pride, preſcribes narrow Bounds to Pleaſure, and condemns Injuſtice and Intereſt. Paſſion being mortified, would deſtroy the Source of its Torments; the Heart being ſeduced, revolts againſt him who holds it between his Hands; it errs, it draws over or endeavours to draw over the Judgment into its Errors, in order to withdraw itſelf from the importunate Idea of Puniſhment. It exhauſts itſelf in Hypotheſes to make Conſcience ſilent. Conſcience that cannot be brib'd ſpeaks, makes itſelf to be heard, uſes Reproaches, agitates the Soul, fills it with Diſquietudes, with ſalutary Terrors. Can the Infidel, even in this ſo conſtant Remorſe, hinder himſelf from obſerving the Voice of God himſelf whom he is afraid of acknowledging, and who calls back the Ingrate flying from him.

How long, O Lord, wilt thou ſuffer Ingratitude, in ſpight of the Cries of Conſcience and Reaſon, to abuſe thy Light, and thy Benefits, in endeavouring to annihilate thyſelf? Humble thoſe preſumptuous, unpeaceable Spirits, which rebel againſt the ſupreme Sovereign; *Fill their faces with ſhame.* Strike; and thoſe who do not acknowledge thy beneficent Hand, ſhall feel the weight of thy Arm, falling heavy upon their heads. Finding no more Refuge in Vanity, in trifling Friends, in the Favours of Fortune, they will turn their Eyes toward thee, *And will ſeek thy Name*[c]. Or rather make thoſe pleaſant, but lively and effectual Rays, to ſhine into the innermoſt Receſſes of their Souls, which have ſo often triumphed over the Ungodly. And the Unbeliever joining at laſt his Voice with that of all wiſe and judicious Men, will glory to bleſs and adore with Submiſſion the mighty Hand which called both the Heavens and the Earth out of Nothing: *And they ſhall worſhip before thee, O Lord*[d].

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[c] Pſalm lxxxii. [d] Pſalm lxxxv.

The End of the Third Volume.